AN INNOVATION GUIDE FOR
CIRCULAR CHANGE AGENTS

FUTURE ADAPTIVE DESIGN

How to create longer-lasting products for circular offerings

RISE – Research Institutes of Sweden
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Significant financial and environmental values are lost when valuable products are discarded prematurely. Elevators are in many cases scrapped prematurely for material recycling although remanufacturing and upgrades can save most of the embedded values.

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Edited by Anneli Selvefors and Thomas Nyström

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Published by RISE 2023

RISE report number 2023:74

ISBN 978-91-89821-51-4 (digital version)

Please cite this guide as: Selvefors, A. & Nyström, T. (Eds.). (2023). Future Adaptive Design – How to create longer-lasting products for circular offerings. RISE. RISE report 2023:74. ISBN 978-91-89821-51-4.

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Longer product life – a threat to business, or a way towards long-term profitability and reduced environmental load?

The vision of a circular economy proposes that companies can become more profitable and sustainable by adopting so-called circular practices. This aspiration has inspired many manufacturing companies to start their transition journey from a traditional linear to a more circular business by exploring how to close material flows, improve eco-efficiency, and utilise renewable energy. The opportunity to extend product lifetimes, however, remains underexplored although it has potential to contribute significant environmental benefits.

Some may see longer product life as a threat to business since it may negatively affect sales of new products and profitability for companies dependent on linear business logic, especially for those that produce and sell products in large volumes. The idea of extended product lifetimes challenges traditional logics of designing for a reasonable lifetime or planned obsolescence. In this guide, we argue that longer product life can be a pathway towards long-term profitability and value capture within the limits of the planet.

Emerging global trends also favor longer-lasting products. Upcoming legislation will put more pressure on manufacturers to enable repair, offer spare parts, and provide information about expected product life. More frequent material and component shortages as well as price volatility will make excessive material use less profitable. Rising global consumer awareness will also pressure companies to deliver longer-lasting products.

In this guide, we present practical ways to design products for extended lifetimes that are suitable for circular business models, which have the potential to preserve and capture embedded values over time. We believe that companies that design, manufacture, or offer durable goods are the ones that can benefit the most from finding ways to extend product lifetimes. Companies that develop and offer fast-moving consumer goods or consumables can nevertheless also benefit from considering opportunities to increase longevity.

This guide is for change agents who have already started or who want to take on the challenge of designing longer-lasting products and implementing circular business models. This includes designers and engineers, business and design managers, and those in top management that create enabling conditions so that products can be designed for longer lifetimes.

CONTENTS

The roof section of Lom stave church in Norway was built around year 1170. The modular wooden architecture has been replaced and upgraded over the years, exemplifying how product longevity can be achieved in practice by combining a suitable product architecture with long-lasting materials.

A traditional timber cabin can illustrate the basic principles behind Future Adaptive Design. Its modular architecture takes potential future changes into account and utilises quality materials, making the house durable, easy to maintain, flexible and adaptable as new needs arise over time. New technologies, such as solar panels and better insulation, can be installed as they become available. Such upgrades can generate more energy than utilised, create new revenue streams for the owner, and contribute to keeping the total lifecycle cost low. They will also enable owners to increase the cabin's value over time.

I.
WHAT IS FUTURE ADAPTIVE DESIGN?

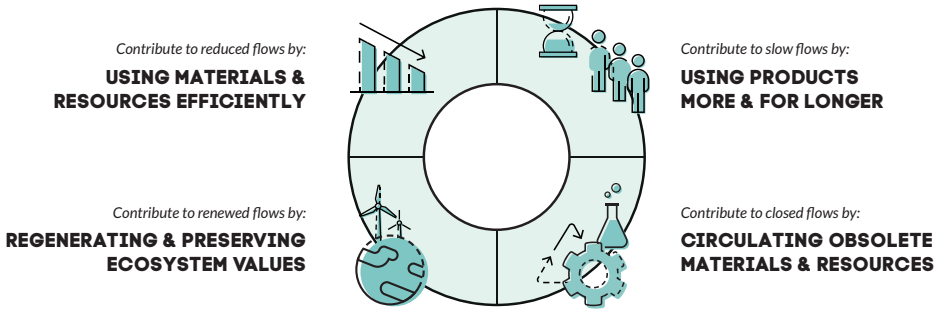
The limited carrying capacity of our planet calls for an alternative way of utilising our resources. Instead of the prevalent make-use-dispose economy, there is a need for a transition to a circular economy that can reduce the throughput of resources and decouple economic growth from environmental degradation. In contrast to the linear logic, a circular logic is built on value preservation and circular flows. It favors products with long lifetimes that can be systematically repaired and reused many times, upgraded and remanufactured when needed, and as a last resort recycled.

Products should not only be long-lasting when it comes to performance; products must provide long-lasting functionality and aesthetics, and also be able to adapt to unforeseeable futures in which consumer needs, policies and technologies may change in ways that cannot yet be predicted. Such products have potential to not only stay contemporary but to be improved over their lifetime when new technologies and materials becomes available.

In this guide, we introduce Future Adaptive Design, FAD, a new approach to design for extended product lifetimes. FAD helps companies explore opportunities to increase product longevity in early phases of development. It proposes a new design logic based on longevity and supports companies to pursue adaptive designs while also adjusting their business models and organisations to increase the potential for improved profitability and environmental performance. By supporting companies to align design, business, and organisation logics, FAD can help reinforce a circular logic focused on longevity throughout the organisation.

Future Adaptive Design – one approach to design for a circular economy

Somewhat simplified, a circular economy can be described as a vision of a future economic system that does not generate waste and that is powered by renewable energy. In theory, it can enable humanity to live well within the limits of the planet while contributing to the preservation and regeneration of ecosystems. From a material and resource flow perspective, a more circular economy can be realised if products and services are designed according to the following principles: *Using materials & resources efficiently*; *Using products more & for longer*; *Circulating obsolete materials & resources*; and *Regenerating & preserving ecosystem values*.



Four circular strategies that reduce environmental impact by contributing to reducing, slowing, closing and regenerating material and resource flows. Adapted from Konietzko, Bocken, and Hultink (2020).

Combining these four circular strategies when designing products and services will increase the potential to influence global materials and resource flows over time. Positive effects may include decreased amount of primary material and resources used for production; a slower extraction of finite materials and resources; closed material flows with less leakage; and preserved and restored ecosystems. Although the potential impact of each strategy varies from case to case, all four strategies are important and should be considered when exploring circular opportunities.

We recommend starting with the strategies that hold the biggest potential for environmental improvements. For many durable goods, the most important strategy is to use products for longer thus spreading out the environmental burdens needed to produce them over more lifetime and contributing to slowing down global material flows. Exploring opportunities for prolonging product lifetimes is the focus of FAD and the main topic of this guide.

USING MATERIALS & RESOURCES EFFICIENTLY

Materials and resources are used efficiently. Includes designs that use less material and resources to create the same benefits.

Example: Eduards Accessories – The Leather Archive Project. *Bags and accessories made of leftover materials to reduce the need for new raw materials and material processing.*

USING PRODUCTS MORE & FOR LONGER

Products are used more and for longer. Includes designs fit for high utilisation, upgrades and/or refurbishments so that their value and function can be preserved over time.

Example: Flokk – New RH logic. *Office chairs designed for a minimum of twenty years of usage. Easy to maintain and disassemble to enable repairs and upgrades.*

CIRCULATING OBSOLETE MATERIALS & RESOURCES

Obsolete materials and resources are circulated. Includes designs that contains recycled materials and can be recycled.

Example: Sculptur. *High end 3D-printed chairs that are made of scrapped and recycled bumpers from cars and can be circulated in multiple loops.*

REGENERATING & PRESERVING ECOSYSTEM VALUES

Ecosystems are preserved and regenerated. Includes design that use non-toxic and renewable resources and energy.

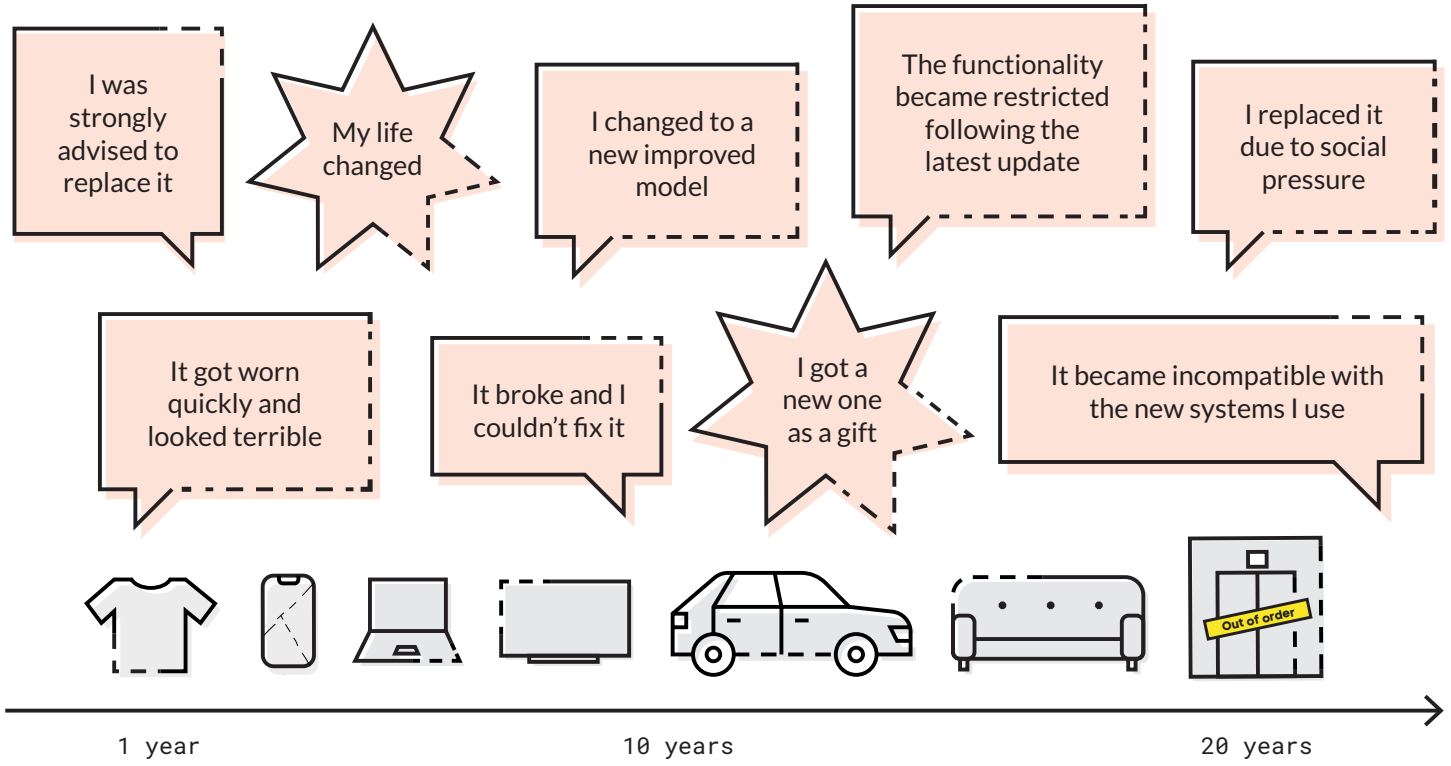
Example: Perstorp – Project AIR. *CO_2 captured from fossil-based production is turned into methanol that can be used as fuel or for polymer production.*

Risks for premature product obsolescence

A product can be considered obsolete when it is no longer in use, perceived as desirable, or useful for its intended purpose. Sooner or later, all products will become obsolete, and people and organisations will either leave them unused or discard them and replace them with new ones that better fit their needs.

In most cases, such replacement decisions will be influenced by a mix of different drivers of obsolescence. These drivers are often intertwined and when present, they speed up people's replacement decisions and contribute to premature product obsolescence. Premature obsolescence in turn contributes to global waste streams, loss of values embedded in discarded products, and lost potential for capturing value from unutilised and idling products.

In this guide, we differentiate between four main drivers of premature product obsolescence: Technical obsolescence; Functional obsolescence; Aesthetical obsolescence; and Social obsolescence. These drivers may make people consider a product obsolete and discard it prematurely.



The expected lifetime of durable products depends on many factors. Some are related to the development and production of the products; optimising for cost-efficient production can reduce quality and utilising fast-paced technologies can make products irrelevant quickly. Others are related to how people use the products; accidents and careless usage can result in broken products or reduced performance. There are also factors related to societal norms, contextual conditions, and people's everyday life.

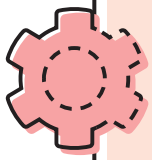
What is planned obsolescence?

Since obsolescence usually triggers people to replace products with new preferable ones, planned obsolescence has been a noticeable strategy for linear businesses for several sectors. For instance, it has been practiced in the fashion industry since the 18th century and applied also for capital goods during the great depression (see for example Waldman, 1993; Packard & McKibben, 1960; London, 1932). To increase consumption, new fashion collections were launched every season making the older ones look outdated and old-fashioned. This was soon adapted by the car industry in the 1920s and became an important strategy for many other consumer goods shaping consumers' lifestyle and identity.

Waldman, M. (1993). A New Perspective on Planned Obsolescence. The Quarterly Journal of Economics, 108(1), 273–283.

Packard, V., & McKibben, B. (1960). The waste makers (Vol. 35). New York: David McKay.

London, B. (1932). Ending the depression through planned obsolescence (pamphlet). New York: Madison.



Technical obsolescence

Reduced technical performance caused by mechanical failure (e.g., due to wear or breakdowns) or the introduction of new superior technological innovations that cause existing products to become perceived as inferior and lower performing.

Examples:

Products that are broken or worn to the extent that their performance is reduced, or products that rely on old technology such as VCRs, floppy disks, and cables with old connectors.

Functional obsolescence

Reduced ability to provide functionality that meets customer/user needs over time (e.g., changing need for increased space, or dimensions), which give rise to mismatches between provided functionality and desired functionality.

Examples:

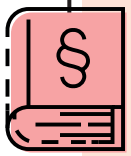
Products whose functionality is no longer useful for the customer/user, such as outgrown clothes, computers with too weak processing capacity, and mobile phones that are not 5G-ready.

Aesthetical obsolescence

Reduced ability to meet visual requirements due to changing product appearance (caused by e.g., scratches, blemishes, or fashion changes), which give rise to mismatches between actual appearance and desired appearance.

Examples:

Products that look worn or non-contemporary, such as unfashionable clothes, worn furniture, and cars with scratched exteriors.



Social obsolescence

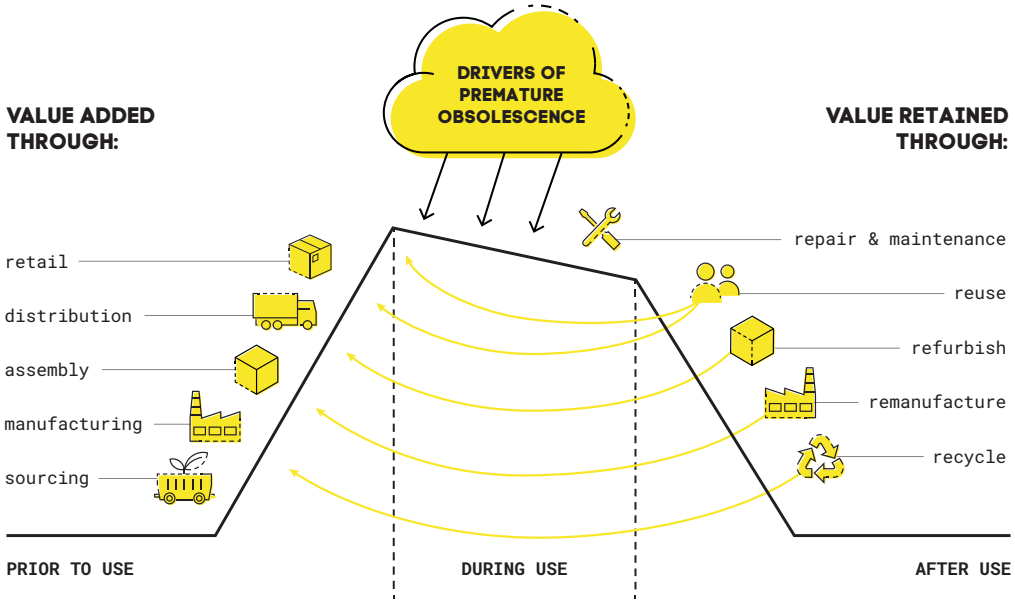
Non-compliance with legislation or changing societal trends, e.g., products that are unable to comply with new certification rules or emissions legislation, or products that do not gain acceptance by customers/users in changed usage situations.

Examples:

Products that contain restricted substances, emit illegal emissions, or don't comply with social norms, such as cookware with harmful coatings, refrigerators with ozone depleting refrigerants, and fur clothing.

Although obsolescence may benefit linear businesses short term, the four drivers of obsolescence can also have negative impacts on their business models. Lost market shares, high costs for new product development, and difficulties complying to future legislation are just some of the risks that the four drivers of obsolescence may give rise to for linear business models (LBMs).

Companies that rely on LBMs and offer products that run the risk of becoming prematurely obsolete will not be able to benefit from the value that has been embedded in their products through production, other activities, and investments. However, shifting to circular business models (CBMs) and designing adaptive products presents opportunities that can help alleviate these risks and increase the potential for future value capture.



The value hill illustrates how value added "uphill" during refinement of natural resources and production of products is reduced during the use phase and lost "downhill" unless solutions for circular value capture are in place. Drivers of premature obsolescence can speed up the process and contribute to lowering the embedded value over time. The possibilities to capture value before or after a product has become obsolete are often dependent on the design of the products and the business models of the providers. Adapted from Achterberg, Hinfelaar, and Bocken (2016).

Risks for companies reliant on LBMs

Technical obsolescence
Offering low quality products increases the risk of complaints and lost market shares. Offering products that are difficult to maintain, repair and upgrade reduces the possibility to capture additional value after point-of-sale. Offering products with technology know to soon become obsolete reduces sales over time.

Functional obsolescence
Offering products with fixed functionality limits the product's relevance for different usage scenarios and for continued sales over time when functional requirements may shift.

Aesthetical obsolescence
Offering products with a particular style, expression, or color may make them less relevant for customers long term, which will necessitate investments in continuous development of new products to ensure continued revenues.

Social obsolescence
Offering products incompatible with social trends can increase the risk of boycotts and weaken the brand. Offering products that are non-compliant with upcoming legislation covering circular requirements will be unfit for sales.

Opportunities for companies shifting to CBMs and FAD

Technical obsolescence
Offer durable, repairable, and upgradable products that can endure increased usage to enable value capture over a longer period through CBMs. Offer products that can be adapted to, and compatible with, future technologies to stay ahead of the curve in industries with high innovation pace.

Functional obsolescence
Offer products that can meet both current and future functional requirements to keep the product relevant for longer. Offer products that can meet functional requirements for different usage situations to make the product relevant to more customers and use scenarios.

Aesthetical obsolescence
Offer products that stays attractive over the whole lifecycle to enable value capture throughout multiple use-cycles.

Social obsolescence
Offer products that can adapt or adjust to changing social trends to enable value capture also in future unforeseen scenarios. Offer products that enable exchange of parts and materials to comply with new legislations or certification requirements.

Circular business opportunities

A business model is often described as a blueprint of a company's "core" logic of doing business. Business models reflect the way value is created by addressing customers' wants and needs, how the values are delivered, and how the company captures the values and make a profit. Values can be both monetary and more intangible values, such as attachments to products and services, and brand values.

Business models come in many shapes and can vary in character. Traditional linear business models most often rely on revenue from point of sales and consumables and are often coupled with a design logic focused on optimising products for production and point of sale. Circular business models, on the other hand, seek to profit from the total product lifecycle and rely on that products are optimised for the intended use.

Circular business opportunities rely on new logics for value creation, delivery, and capture, which are focused on retaining material and immaterial values. Examples of circular business opportunities include Product life extension, Product-as-a-service (PaaS), Sharing, Circular supply, and Resource recovery (Circular Advantage, Accenture, 2014). Several of these can be relevant for a specific company and multiple business models can be run in parallel. Since FAD aims to primarily contribute to long-lasting products, FAD is especially relevant for the business opportunities Product life extension and Product-as-a-service. However, by combining these models with components from other CBMs, companies can increase the potential for reducing lifecycle costs, increasing, and stabilising revenues, and realise environmental benefits.

There is not a silver bullet CBM that fits all companies' ambitions and practical possibilities to go circular. Capturing values by extending the useful life of products requires commitment and possibilities to manage product health and health history. Legal ownership is also crucial if products are used as collateral in financing a PaaS model.

Circular supply

secondary materials (e.g., recycled materials) are used instead of primary materials (providing circular inputs) for production of goods

Example: Houdini Sportswear
Outdoor clothing with more than 80% of the collection based on recycled and recyclable ingredients.

Product-as-a-service

companies offer customers access to products rather than ownership (e.g. rental)

Example: Mitsubishi M-USE
An elevator-as-a-service offer guaranteeing property owners up to 50 years of functional life.

Product life extension

the useful lifetime of products is extended through design to enable longevity and multiple use-cycles (e.g., repair or remanufacturing)

Example: Fairphone
Smartphones designed to be modular and partly upgradable to enable a functional life of 5+ years.

Sharing

product owners are enabled to increase utilisation of their products by sharing use, access, or ownership (often though digital platforms)

Example: GoMore car sharing
A peer-to-peer sharing platform that enables people to rent and share their cars.

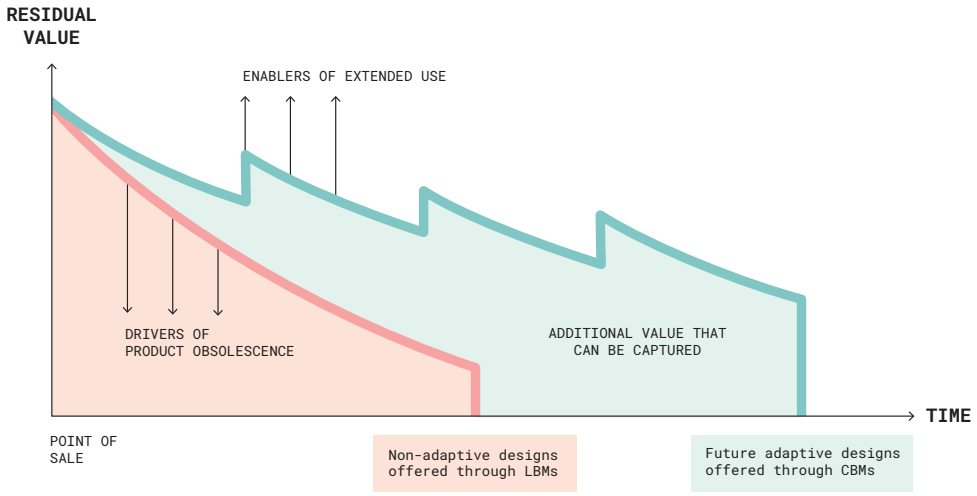
Example: LKAB
Rare earth minerals can be recovered from mining waste. These metals can be used in the production of various electronic devices, and help to reduce the demand for virgin materials.

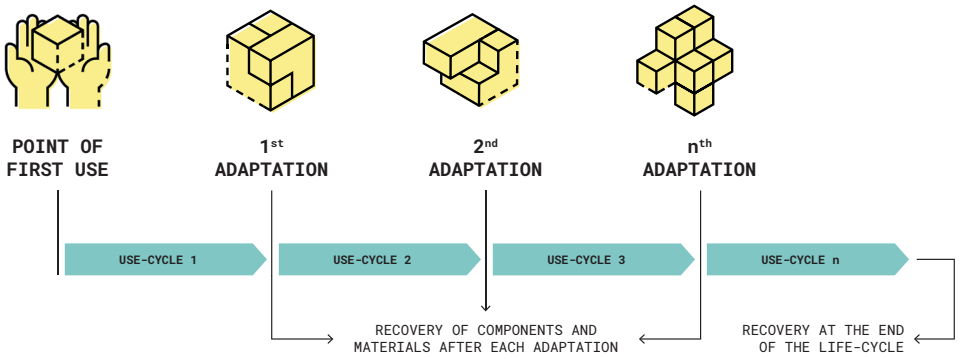
Resource recovery

materials are recycled with renewable energy (creating value from outputs)

Benefits of applying Future Adaptive Design to extend product longevity

Today, many companies that rely on linear business models have difficulties to take advantage of the material and immaterial values that have been embedded in their products during sourcing, production, and distribution. For most durable products, the embedded financial value decreases with use and over time, which reduces the residual value that can be captured when products are considered obsolete by the user. Competing stakeholders may also try to capture the residual values by buying used products and including them in their own offers, making it difficult for the original manufacturing company to benefit from previous investments. When shifting to circular business models that make it easier to capture embedded values, it also becomes more relevant to move away from the prevalent focus on minimising investments and costs during production and focus on preserving product values and reducing overall lifecycle costs. With FAD, companies can gain a better understanding of potential future risks that can reduce the residual value and identify opportunities for necessary adaptations over time. By designing adaptive products and shifting to circular business models, companies can manage and retain embedded values to a higher extent.





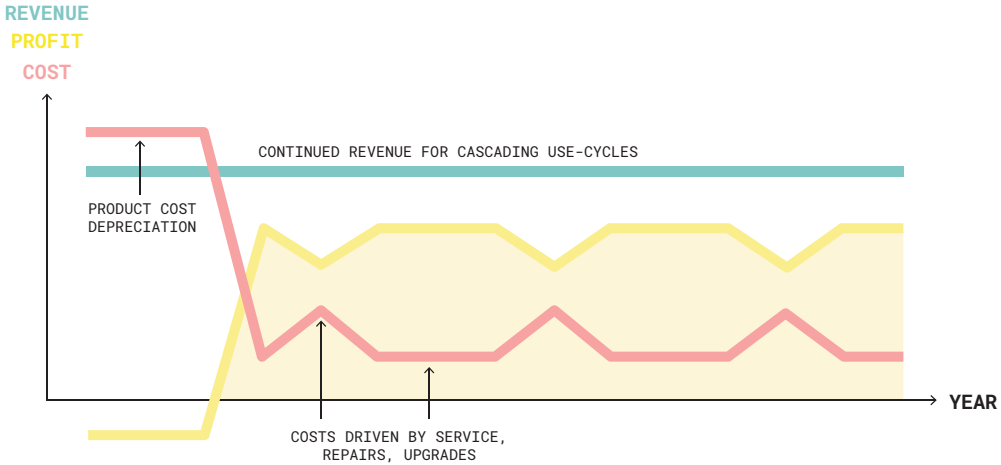
Designing products for multiple use-cycles with planned adaptations that improves the product over time offers potential for reduced environmental load and for retaining embedded values that can be utilised in circular business models.

FAD advocates a shift in focus, from designing for one use-cycle and static design requirements to designing for an extended product lifecycle that include multiple use-cycles with different design requirements. Products designed to be future adaptive will enable several adaptations throughout their lifecycle, including adaptations that enable convenient repairs or allows for upgrades and integration of new technological innovations that ensure that they meet customer needs over time.

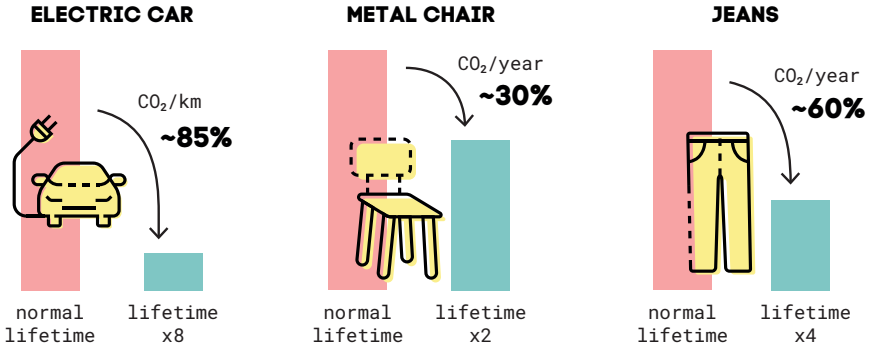
By designing and offering such products, companies can retain, and possibly add, embedded product values over time and significantly reduce potential business risks. Future adaptive designs can hence increase the potential to capture financial values through new business models based on product longevity and circularity and help make such business models more commercially profitable. Moreover, making products adaptive to future conditions and requirements may contribute to decreasing their environmental impact.

The opportunities to reduce the environmental load vary however depending on the specific case and the extent to which longevity and future adaptivity can be ensured. Combining several of the four aforementioned circular strategies can help to increase the potential, as can a combination of several circular business models. It is important to remember that implementing any one circular business model does not necessarily equate to a shift to a more “sustainable mode of operation“; its overall environmental and societal benefits must be assessed on a case-by-case basis.

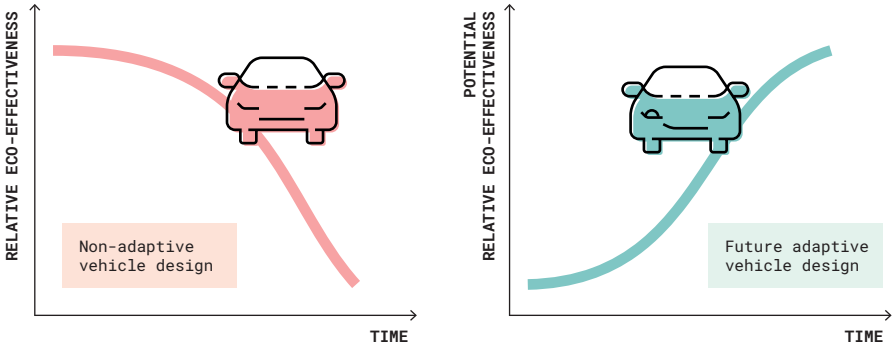
Examples of potential benefits



How does an extended lifetime influence revenues, costs, and profit? Circular business models based on offering access to products have potential to increase profitability over time but depend heavily on the design of the products used. They must be durable and designed for extended use in terms of their performance and functionality to generate profits well after the products have been depreciated and to keep costs low over time.



How does an extended lifetime influence a product's environmental load? A product's environmental impact is often measured in relative terms, i.e. impact per function (e.g. kg CO_2 per km) For many durable products, an extended functional life significantly reduces the relative environmental impact by spreading the impact needed to produce it over more function. Here, potential carbon emission reductions for three products – an electric car, a metal chair and a pair of jeans – are shown.



A traditional non-adaptive vehicle design can likely be maintained and modified within original specifications, but it is unlikely that it can be adapted to new requirements without extensive costs. Since the components' performance will degrade over time, its eco-effectiveness will decrease over time both relative to its original performance and to that of new technology introduced on the market. Consequently, extending the life length of non-adaptive vehicles is not always beneficial. In contrast, a vehicle with future-adaptive design can likely be kept in good condition longer, and key modules can be upgraded with new technology that can potentially increase its relative eco-effectiveness over time. For example, changing from a combustion to an electric engine, upgrading the battery capacity, and updating the software, could make the vehicle more eco-effective, although such changes will have legislative challenges on some markets. Moreover, replaced modules can also be used for other applications, which may further reduce the environmental burden allotted to the vehicle.

Want to learn more?

These estimates come from three research studies carried out by RISE:

- *Nyström et. al. (2023) Adaptive design for more electric vehicle miles, through circular business models (FAD-EV). FFI project report. Dnr: 2019-027646. Swedish Energy Agency project number: 50188-1. (In Swedish)*
- *Bolin et. al. (2017) Hållbarhetsanalys av cirkulära flöden. SP-rapport 2017:32. (In Swedish)*
- *van Loon et al. (2021) Linking circularity metrics at product and society level (LinCS). Swedish Environmental Protection Agency. Report 6971. ISBN 978-91-620-6971-1.*

Building blocks for longevity

Product obsolescence can be described as a product's inability to meet both current and future requirements. Although current requirements can be easy to identify and design for, future requirements are often more difficult to anticipate and some are unforeseeable. An important starting point when designing adaptive products is therefore to consider what is known and likely to happen, as well as possible surprises that could make a product obsolete in the future. In addition to ensuring a durable design fit for an extended lifetime, companies can design products that can adapt to hard-to-predict changes that may occur in the future.

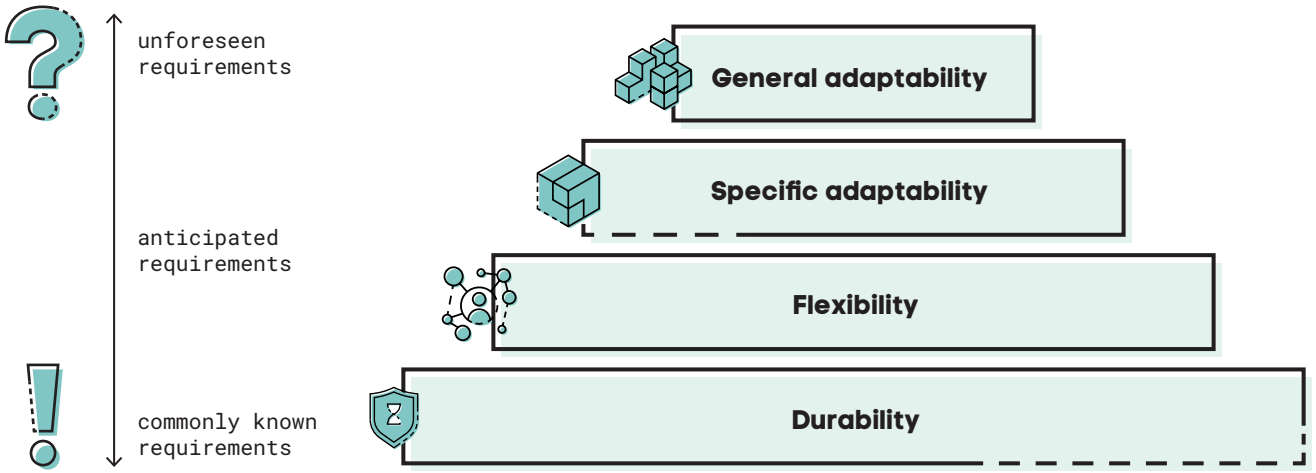
However, it is important to note that companies can only design a potential to avoid obsolescence and extend a product's useful lifetime. Unforeseen events, such as failures, accidents or lower customer acceptance than envisioned, might lead to a shorter lifetime.

When designing adaptive products, four buildings blocks alleviate risks of obsolescence and future uncertainties and enable longevity. Durability can be viewed as the first building block on which the others rest. Durability makes a design resistant to wear and tear so that it can endure an extended lifetime and multiple use-cycles.

Although a durable product can last a long time, it may not be useful nor resource-effective long-term if new functionalities and technologies with better environmental performance cannot be integrated. For instance, for energy-using products such as automobiles, it becomes especially important to consider how the design can enable future upgrades and adaptations. It is therefore important to also consider the other buildings blocks.

Flexibility deals with how a product's functionality fits for different usage situations. Adaptability deals with both anticipated and unforeseen requirements and can be either specific or general. Specific adaptability is focused on how to make a design adaptive for specific changes that are predictable, whereas general adaptability deals with how the complete architecture can adapt to unforeseen changes.

These building blocks can both be considered as a typology to choose from, and a hierarchy to relate to during the development process. Depending on the type of product, and the usage scenarios planned for, there will be reasons to aim for the lower building blocks, as well as aiming higher up to be able to account for more possible unknown business risks.



The four main buildings blocks for longevity address obsolescence and future uncertainties in different ways and to different degrees. Durability can be viewed as the foundation on which flexibility, specific adaptability and general adaptability rest. While durability addresses common design requirements known to be relevant long term, the other building blocks deal with future anticipated and unforeseen requirements.

For a component that will not be exposed to any known changes in technology, a primarily focus on durability might be enough. For more complex products, a focus on flexibility might offer a potential for reduced cost if one product can replace multiple ones. Moreover, when a set of possible scenarios with known or probable future upgrades are planned for, it makes sense to aim for specific adaptability. General adaptability, on the other hand, requires a much more holistic approach where present and possible future needs are balanced in the design process to take into account possible surprises that can pose severe business risks or revenue potentials. Although such an approach will be more challenging and likely require more investment, it has no clear limitations for possible future adaptations.

General adaptability

The whole product architecture is designed for future adaptations to preserve embedded and perceived product values for owners, service operators, customers, and users. Enables future adaptations to needs and requirements unknown at the time when initially designed.

Examples:

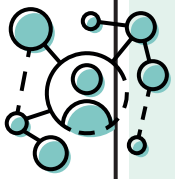
An aircraft designed so that its physical space and infrastructure are reconfigurable to support numerous yet unavailable future systems, i.e., allowing for future changes that are unknown at first launch on the market.

Specific adaptability

The product is designed so that some predefined parts can be exchanged over the product's planned life-cycle. Enables adaptations to needs and requirements that can be foreseen at the time when initially designed.

Examples:

A laptop designed so that its RAM and HDD can be exchanged and upgraded with specific components to improve its performance.



Flexibility

The product is designed to provide multiple functions without significant alteration. Enables flexible use in multiple usage situations and reduces the need for multiple products.

Examples:

A Swiss army knife that offers multiple functionalities in one product. A smartphone designed for two sim-cards which enables the user to switch between business and private calls on the same handset.

Durability

The product is designed for extended endurance and operating cycles by resisting physical and visual wear. The design also enables repair and replacements that can restore it to its original specifications.

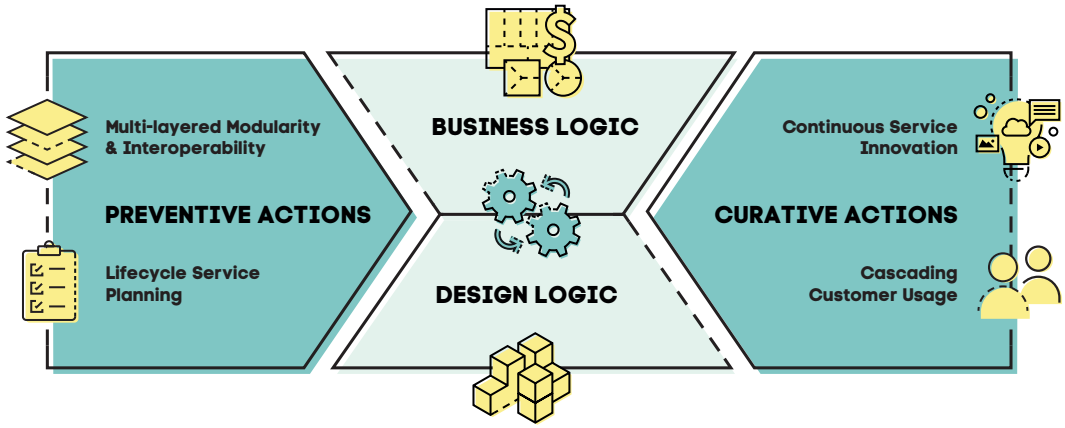
Examples:

Materials and components that are specified and tested to withstand physical and visual wear over a specific use cycle in years, kms, hours, etc.

Strategies for Future Adaptive Design

Companies can address the risks of premature obsolescence, find the right balance of the various building blocks for longevity, and contribute to longer lifetimes through two main approaches. In early phases of design, companies can work with preventive actions to design products fit for longevity and adaptivity and also design for curative actions applied throughout the lifecycle. Preventive actions aim to improve the product's ability to retain value and resist premature obsolescence through a product architecture that enable modifications throughout its lifecycle. Curative actions are associated with the promotion of processes and technology approaches that can be applied to products at different stages in their lifecycle to add value and avoid premature obsolescence. The Preventive and Curative actions cover four design strategies that highlight how product-related business risks could be mitigated.

Preventive actions deals with strategies that aim to support ideation around opportunities that can make the product architecture both more modular and interoperable, and that can enable components to be exchanged and upgraded over the product's lifecycle. Curative actions cover design strategies that support ideation regarding how to develop new service content that can keep the product attractive, or when not possible anymore, how to find customers willing to pay for a used product or components in a cascade.



The FAD framework includes two main approaches to address future uncertainties in early phases of design: (1) Actions that can prevent the product architecture from becoming premature obsolete and (2) curative actions that can capture value from an existing product by adding new content, or from obsolete components. Depending on type of product and use cases these two approaches can be elaborated and balanced between drivers for circular business opportunities, versus feasibility from design and technology.

PREVENTIVE ACTIONS

Multi-layered Modularity & Interoperability

Focuses on opportunities to design the product architecture to support interventions that allow for updates (over the air) and component changes over the product's lifetime. Highlights ways to postpone and reverse premature obsolescence by making components easy to upgrade or exchange when faulty, which are relevant for technical, functional, aesthetical, and social obsolescence.

Lifecycle Service Planning

Focuses on opportunities to design interventions to exchange, update, and replace components throughout a product's lifetime to maximise its useful life. Highlights ways to plan for lifecycle services activities for components and technologies that might need to be exchanged and upgraded over a product's lifetime, which are especially relevant for technical and aesthetical obsolescence.

CURATIVE ACTIONS

Continuous Service Innovation

Focuses on opportunities to design additional services or product add-ons that address changing customer needs to ensure that the product stays relevant for an extended period. Highlights ways to give customers a continuously contemporary product experience based on the existing hardware (reducing their need to replace the product), which are especially relevant for aesthetical, functional, and social obsolescence.

Cascading Customer Usage

Focuses on opportunities to design new offers that utilise existing products and components for new applications and customer groups to maximise utility. Highlights ways to provide the product owner with a possibility for a revenue stream from resale of exchanged components, remanufactured components, or recyclable materials, which are especially relevant for technical and functional obsolescence.

Multilayered Modularity & Interoperability

The strategy Multilayered Modularity and Interoperability addresses the opportunity of a layer-based product architecture that enables a product's components to be interchanged and updated as independently as possible over the product's lifetime. A layer-based product architecture enables changes to one layer without affecting the other layers. It hence allows for efficient disassembly and layer-wise repairs, upgrades, and reuse of components. Interoperability, or the ability for these layers to remain compatible with each other, is a prerequisite to ensure that the product still function properly when components are replaced, or new ones added.

A product's components can be structured in layers based on their functionality and obsolescence-driven replacement needs. Using a human body metaphor, a layered product architecture can be divided into five main layers: Skin, Organs, Skeleton, Metabolism, and DNA.

The skin layer represents visible or tactile product components, such as physical surfaces and digital interfaces that can be experience through product usage. Components that belong to the skin layer primarily risk becoming aesthetically outdated due to wear and tear, material aging, or fashion trends. If skin components commonly become obsolete due to physical imperfections, they should be made more durable and easier to maintain and repair. In contrast, if the expected exchange pace is high due to fashion trends, they should be designed to be primarily exchangeable, recyclable, and produced from already recycled content.

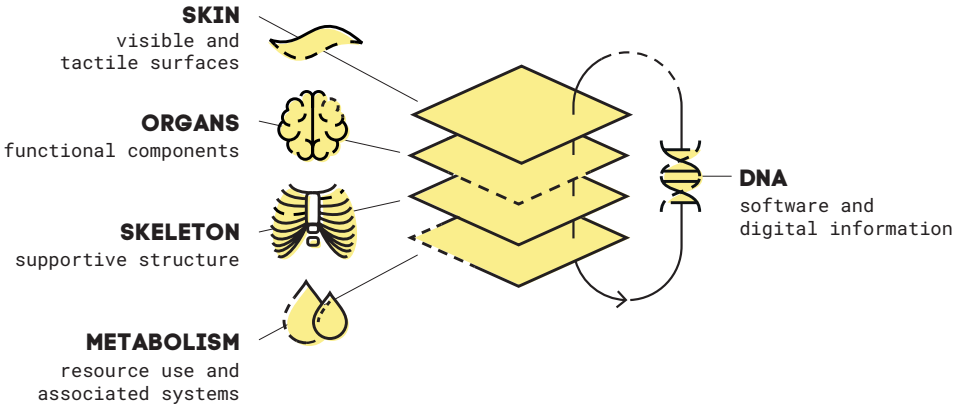
The organs layer represents components or subsystems associated to specific functions, such as mechanical movement, data processing, communication, and energy storage. Organs mainly risk becoming technically and functionally outdated, which will often render the whole product obsolete. To avoid products becoming obsolete due to one or more failed organs, all organs should be designed to be easy to exchange, repair and upgrade.

The skeleton layer represents an internal structure that provides a strong base for the other layers. It should provide a stable structure over the product's whole useful life that allow obsolete components in other layers to be exchanged or upgraded. Components in the skeleton layer are often relatively unaffected by obsolete components in other layers, which often makes it possible to preserve their embedded value over the product's whole lifetime. For example, race cars are often designed with a tube frame that functions as a stable crash safety structure onto which a dismountable composite shell is attached. This design allows for easy disassembly, repairs, and upgrades of the skin and organ layers, and reduces the cost of production tools, as for metal stamping of casting.

"The layer-based mindset has stuck with us and it is very useful."

Designer

The Metabolism layer represents use of consumables, energy, and propellants, as well as the systems and components that are needed for utilising the resources. Risks for social obsolescence must be carefully considered since some propellants, consumables, and their associated emissions may be boycotted by consumers or restricted by legislation in the future. If the product relies on propellants and consumables with uncertain futures, it should be designed to allow changes in the product's metabolism. To facilitate such changes, components in the metabolism layer must be easy to replace along with affected components in other layers. For example, if future legislation bans specific ingredients used by a component, the component should be possible to exchange with an updated component without affecting the whole product architecture.



With a layer-based product architecture, a product can be structured in separable but interoperable layers, meaning that a component or material on one layer can be exchanged without affecting the other layers. Most durable products have potential to be divided into such layers today. However, products are often assembled with production methods, and in an order, that make interchangeability difficult, costly, or impossible. In constrast, layer-based architecture can help in combining both cost-efficient production with cost-effective aftermarket activities such as easy dismantling, maintenance, repairs, and upgrades.

The DNA layer represents software and digital information utilised by components in the other layers. Information can include data on material content, product health during usage, and health history, which can be essential to preserve, pass on over time and potentially make accessible to different stakeholders. Information about the product's design, such as technical specifications, engineering drawings, and numerical models, are also part of the DNA layer. The main risk for obsolescence is that the DNA layer can become functionally and socially outdated. For instance, changed user needs or technological advancements can spur new software requirements, and stakeholders or new legislation may require additional or different information than can be provided.

Since the layers differ in terms of when repairs and upgrades can be expected, modularisation within layers are prioritised. Modularisation across layers (i.e. combining and joining components and materials in ways that prevent ease of disassembly) repairs should be avoided as it may force more frequent exchange of components than needed.

Lifecycle Service Planning

The strategy Lifecycle Service Planning focuses on opportunities to maximise a product's useful life by addressing known, anticipated, or potential future risks for premature obsolescence and planning for necessary lifecycle interventions. It includes considering how to extend the product's lifetime by making it both more durable and fit for different lifecycle interventions such as maintenance, repair, or upgrades with new technologies and functionality. Scenarios for different lifecycle interventions can be explored to identify which lifecycle service activities that should be planned for throughout the product's lifetime. For instance, replacement schemes for critical product components could be essential as well as retrofitting components that comply with new hardware standards. The design should also be adapted to facilitate the planned interventions so that associated costs can be minimised throughout the product's lifespan.

Continuous Service Innovation

The strategy Continuous Service Innovation focuses on opportunities to provide evolving hardware, software, or service updates to keep products relevant to users in an ever-changing context. The strategy addresses the risk that unexpected changes in user needs and behaviours over time will make a product prematurely obsolete. Addressing changing customer requirements by developing supplementary services, product add-ons, touchpoints, hardware, or software can increase the potential that the product stays relevant and in use for longer. Existing examples of Continuous Service Innovation include software updates, which are utilised in products such as vehicles and smartphones to introduce new functionality or improve the user experience in existing products. Another example is adding new service content, for instance, enabling delivery of goods to parked cars (in trunk delivery).

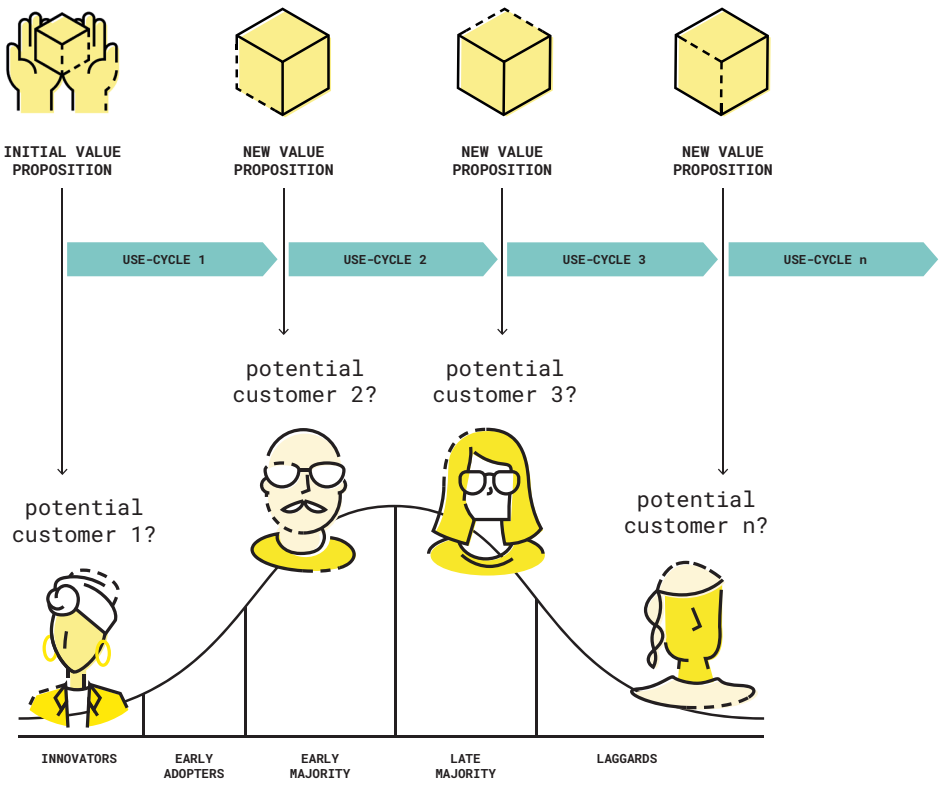
Cascading Customer Usage

The strategy Cascading Customer Usage focuses on opportunities for increasing product lifetimes and product utility through cascaded use of products or components. If it is common that a product is perceived obsolete by the initial customers, one opportunity is to develop additional value propositions for new customer segments that may still find the product useful due for other needs. Such cascaded value propositions can keep the product in use for longer through additional use-cycles without the need for major adaptations. This approach is especially relevant for product segments where costly adaptations can be avoided completely or postponed to future use-cycles.

In contrast, products that commonly require repairs or upgrades to avoid premature obsolescence, can be offered in adapted versions to markets with other requirements. Products that are no longer useful for their initial purpose can also be adapted to fit new contexts and applications, and thus open up for completely new customer segments. Products can also be split in modules so that their components can continue to deliver utility in new combinations for different customers. By utilising these opportunities to systematically offer multiple customer segments cascading value propositions, companies can capture embedded product values throughout multiple use-cycles and identify new revenue streams. This strategy is useful for expensive components as e.g. planning for second-life applications and offerings for high-voltage batteries in cars that can capture remaining values before material recycling.

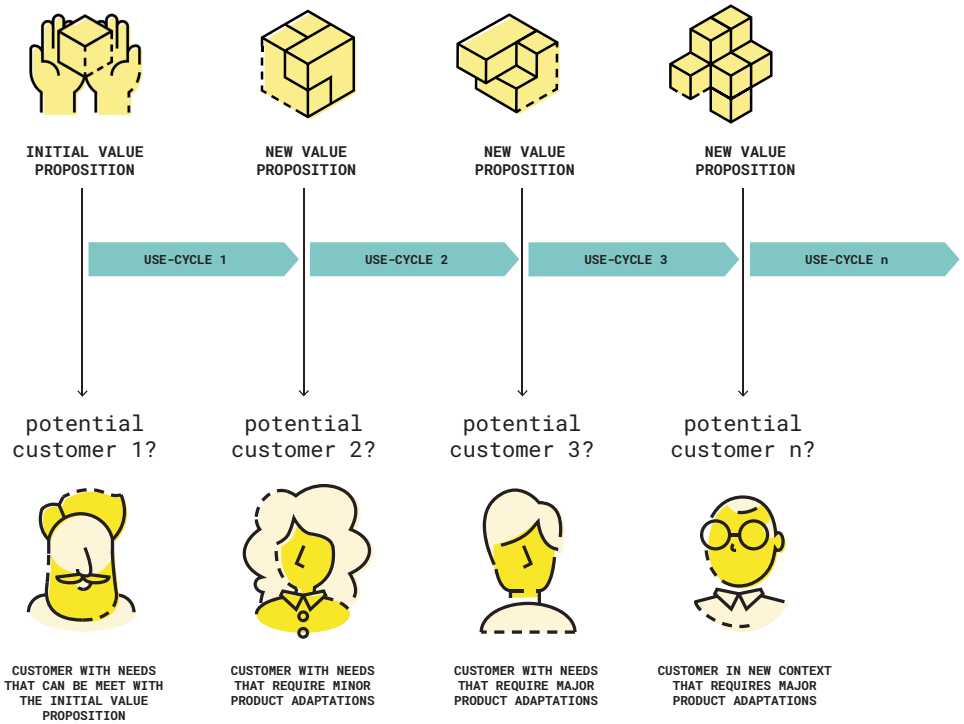
Which customer segments are relevant to consider?

CASCADED VALUE PROPOSITIONS WITHOUT MAJOR PRODUCT ADAPTATIONS



The characteristics of the cascading customer segments may vary in relation to several aspects. They may, for instance, vary regarding how prone they are to adopt an innovation or a new value proposition, aesthetics, brand-loyalty etc. The customer typologies can be divided into early adopters, early majority, late majority, and laggards, as described by the theory Diffusion of Innovations (Rogers, 1962). Innovators may want the newest products and are ready to pay more, while laggards may be satisfied with products that are older, have lower performance, are a bit worn, especially if it means a lower price.

CASCADED VALUE PROPOSITIONS WITH SEVERAL PRODUCT ADAPTATIONS



By using the cascading customer strategy, tailor-made value propositions can be made for specific customer needs over time, while keeping the product contemporary with latest performance. Compared with value propositions without major product adaptations, this approach can capture more of the products embedded values, without relying on price discounts.

II. HOW CAN FUTURE ADAPTIVE DESIGN BE APPLIED IN DEVELOPMENT PROCESSES?

When working with Future Adaptive Design to develop longer-lasting products for new circular business models, it is important to integrate a mindset for value preservation across business divisions and in a range of activities in the early phases of development. To develop successful and adaptive circular offerings we suggest that you start by working from three main activities, with seven sub-activities:

Start by addressing the right things...

A. *Creating a vision for longevity*
B. *Creating a value proposition and iterating through customer dialogues*

continue by designing things right...

C. *Assessing the current state*
D. *Exploring opportunities for Future Adaptive Design*
E. *Assessing business cases based on Future Adaptive Design*

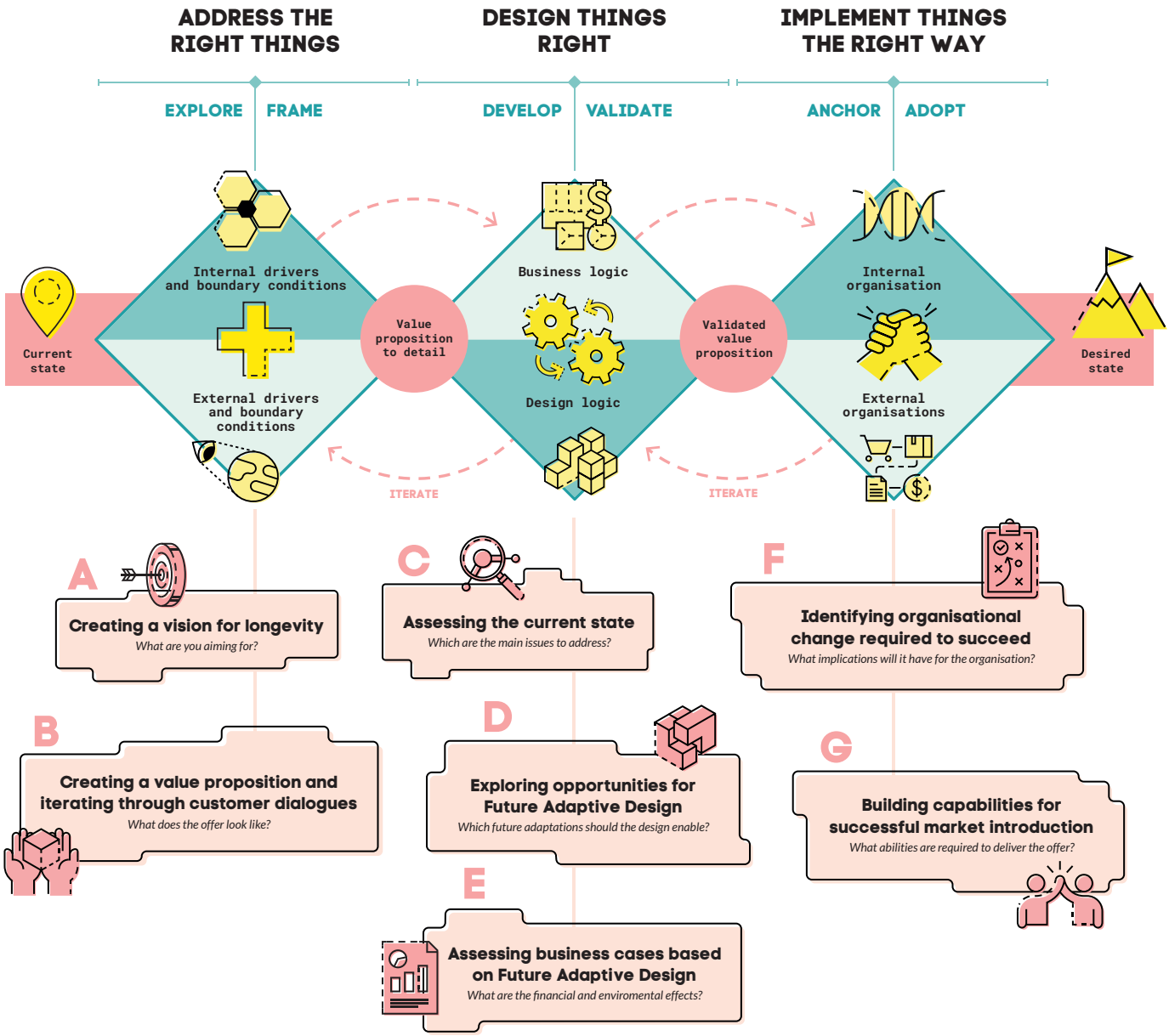
and make sure to implement things the right way

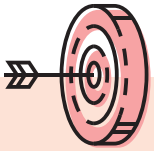
F. *Identifying organisational change required to succeed*
G. *Building capabilities for successful market introduction*

The activities described in this guide provide support in exploring and framing the challenge, developing and validating solutions, and anchoring and adopting solutions in your organisation as well as in external organisations. The activities should not be seen as sequential; they often need to be carried out in parallel and iteratively.

How to best work with these activities in practice varies depending on a variety of factors. For instance, the relevance of these activities depends on if the objective is to adjust an existing product or develop a completely new one. A company´s maturity in (and practitioners' understanding of) circularity and circular business will also influence which areas that need to be addressed. Moreover, as FAD represents just one perspective (extending product life) on how to design for circularity, supplementary aspects such as use intensity, material recycling, toxicity and use of renewable energy should also be considered during development processes.

Before starting to work with FAD, some preparations are warranted. To ensure that there are resources for these activities, you should secure commitment from competences from different parts of the organisation and buy-in from top management. It can be beneficial to set up a dedicated team consisting of people with necessary competencies and functions. We recommend that such a core team include representatives from the business development, design, and sustainability divisions. Then, one can bring in other competences as needed throughout the process. For instance, when exploring FAD opportunities, we suggest that additional colleagues responsible for initial design and development, setting requirements, aftermarket operations, legal matters, and business development are consulted.





ACTIVITY A

Creating a vision for longevity

When defining a vision for extended product life, we recommend that you consider circular opportunities to challenge your business and future offers. For instance, try to challenge the current expected lifetimes of your products. What if the lifetime was say doubled, quadrupled, or taken times x? Start with a bold vision and then, when more detailed information becomes available, revise. We suggest the following when creating a first vision:

- Choose an existing product to base the vision on. It could be a product that represents a major part of your current turnover, or a niche product. You can also use plans for an upcoming product as a starting point. This product should preferably be associated with a high environmental load.

- Discuss and define possible indicators for longevity based on the product chosen. For example, for a car, it could be kilometres driven, for a battery, the throughput of energy over time, for a water pump, the hours of usage, and for an office chair, the number of sittings over time.

- Estimate the potential for environmental reduction by making a rough projection of the environmental burden spread over the extended life cycle. For instance, how much CO_2-eq/km will be emitted over a car's lifecycle. Also consider if it could be relevant to compare your product with other similar products.

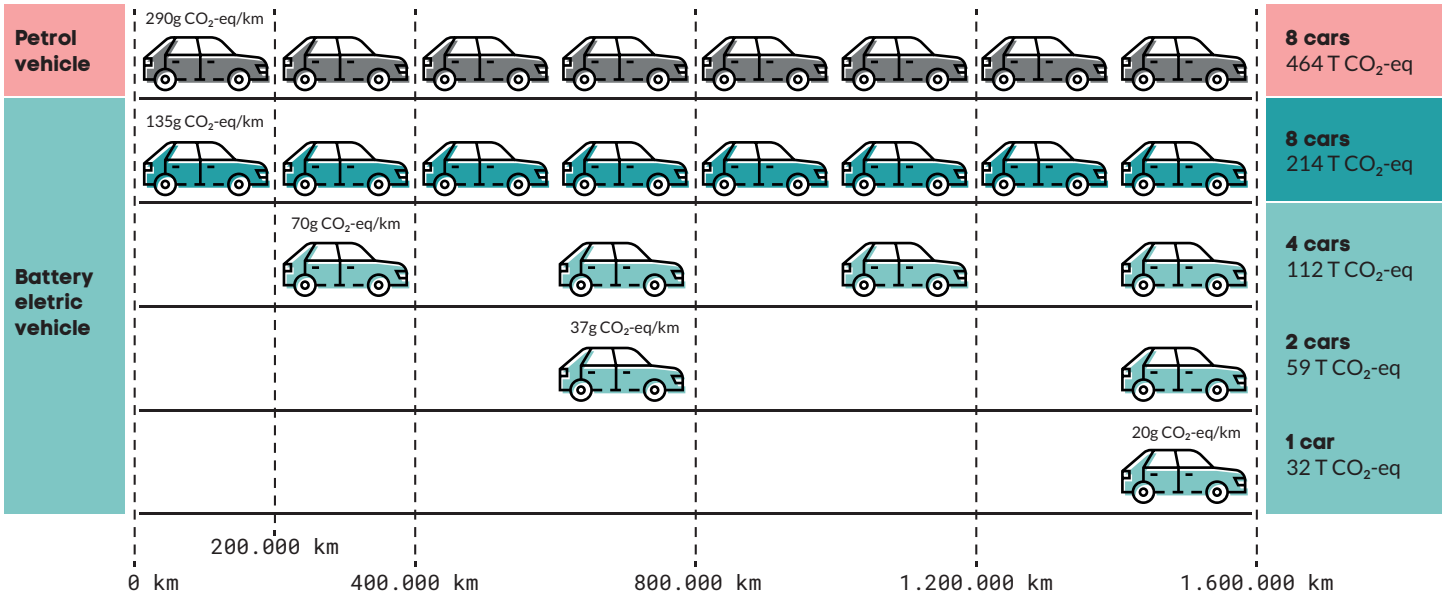
- If needed, you can gather data about the product to help you estimate potential for increased longevity and environmental reduction. This can include a bill of materials (BOM), financial data for the product with component prices, and data on environmental impact from a life cycle assessment (LCA) or an environmental product declaration (EPD). You can also explore current usage of the product by talking with customers and users and observe how products in different usage scenarios have been used and worn over time. Data about complaints and reclamations are also valuable. Additionally, you can identify the legal requirements for the product that is important to consider when creating your vision. Gathering these types of data will be important when assessing the current state during Activity C.

- Create a first vision based on available data, experience, and discussions in the work group. Consider all four circular strategies introduced on page 7. It may be helpful to divide the vision into short- versus long-time scenarios. A short-time scenario can be one to five years, while a long-term scenario reach beyond five years. When developing your vision, you can make use of the tool *Circular vision template*.

Want to get started?

Jump to page 47 to learn more about how to use the *Circular vision template* to define a circular vision.

What if, the traditional lifetime for a car was eightfold?



How does one envision the potential for increased lifetime and increased resource efficiency? If an existing LCA is available, there is an opportunity to base your vision on the data and estimate alternative outcomes based on extended lifetimes. In this example, existing LCAs of a petrol vehicle and an electric vehicle that assumed a lifetime mileage of 200.000 kilometer were used. In order to estimate potential reductions in environmental impact for an electric vehicle with extended life, the assumed lifetime driving distance was multiplied by two, four, and eight, yielding three alternative outcomes with different global warming potential (carbon emissions equivalents per km driven, or CO_2-eq per km). The extended mileage outcomes show a potential for radically reduced CO_2-eq per km and total emissions in tonnes (T) CO_2-eq. This type of illustration can be used as a lens to illustrate implications of extended longevity for the product.

Things to watch out for:

Setting a bold vision for longevity can be difficult. But by considering extreme lifetimes you will view the product in a new light, which will help you to identify both current strengths and weaknesses. Usually, it is easier to start bold and then revise, than the opposite.

A suggestion is to align your vision in relation to other visions for needed environmental reductions as global and national initiatives. For instance, you can align your vision to the Exponential Roadmap Initiative (https://exponentialroadmap.org) or Science Based Targets (https://sciencebasedtargets.org).

Energetic debates about "reasonable" lifetimes are common, especially amongst practitioners. However, most often such discussions are grounded in the existing business logic, and design decisions resulting from it. So, make sure that everyone involved is aware of that this vision is for a future state, and not something that must be implemented immediately. Try to engage in the process without carrying the burden of the current business logic.

See the first vision as tentative. It should be further refined in the innovation process as more details regarding customer interests, willingness-to-pay, and technical feasibility etc. are identified.

ACTIVITY B

Creating a value proposition and iterating through customer dialogues

Strategyzer's tool *Value Proposition Canvas* can be used to map customer pains and gains and explore what value that you can create for your customers.

A product that is loved by customers tends to succeed. But what would make an attractive offer that can compete with the traditional linear alternative? What would the customer be willing to pay for? Since this guide investigates how to design longer-lasting products for circular business models, this should be in focus throughout the process of generating a value proposition. Consider how you can create extra value due to extended product life and how you can capture that value. You can also explore an array of customers willingness-to-pay for older products to identify ways to attract different perhaps more price-sensitive customer segments over time.

Longer-lasting products can be more expensive to produce. Companies with linear business models may thus have to set a high price when offering such products, which can result in a niche volume and in low or lost profits if the products are outcompeted by more affordable solutions. Therefore, such products often need to be offered through a business model where the value can be captured by the one that invested in it – the company. Business models based on kept ownership, like rental and Product-as-a-Service are sensible in such cases. Take-back business models (in which a business takes back products at end-of-use) can also be fitting as the company can capitalise on the residual value of products by selling them multiple times.

Since co-creation and collaboration is crucial in a circular economy, circular value propositions are much more dependent on business ecosystems than linear value propositions. Many create, offer, and run their services together with partners and customers rather than having a strict buyer-seller relationship. Circular value propositions also often include service solutions that involve customer relations and interactions on a more continuous basis. It can be necessary to find new partners with new offerings since they can be the key to achieving transformative solutions.

When developing your value proposition we suggest that you consider these key activities:

- Find out together with customers and partners what value you can create for them. Try to co-create solutions that are not yet on the table and test them. You can explore what jobs that needs to get done and which drawbacks that customers experience with current linear offers. Then consider what pain relievers or gains you can create and put together an initial offer.

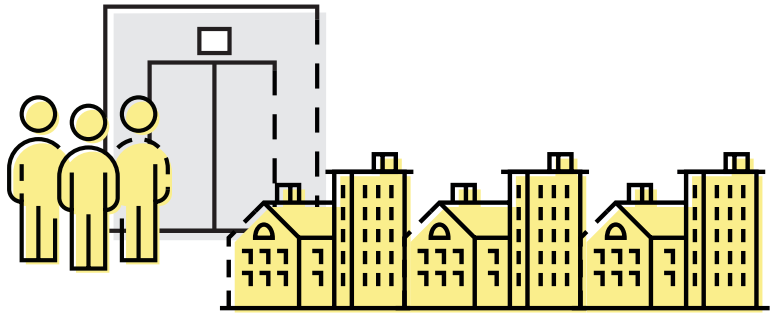
- Parallel to value creation, you also need to assess what the customers are willing to pay and for what. This includes investigating payments options and customers' need for flexibility around payments. Willingness-to-pay can be identified by using multiple choice studies. In such studies, customers are asked to react to different combinations of values based on predefined variables, such as price and performance, and choose the most attractive/least unattractive scenarios. After multiple rounds, the customers willingness-to-pay is calculated for specific scenarios and changes in variables.

- Make sure to iterate the offer with customers and partners early on to find which solutions you should move forward with and to identify unsuitable solutions that should be discarded as quickly as possible so you don't spend time on the wrong things. Aim to keep close contact with the customers and continue collecting data about what they prefer and about what they don't like.

- Consider with which additional organisations you can partner with to create more value or deliver services. When it comes to mapping the (often) complicated business ecosystems in circular service solutions, *Business Model Canvas* and similar tools can be a good start but you will soon need to be more detailed. Tools like *Board Of Innovation* help one detail which material/product, information and money flows occur between different parties. Circular business models often require that data is shared between parties so investigate possibilities for this early on. Lack of shared data is one of the most common reasons that a circular business model fails (Frishammar & Parida, 2021).

- Merge your value proposition with the product planning process. In many industries, the windows where you can change the product design are few, occurs rarely, and one needs to plan for new design specifications far in advance.

What if we remove all our customers' worries about product downtime and maintenance costs?



Mitsubishi M-Use offers vertical meters transported instead of selling elevators. This opens up for a product design which is built for longevity and durability. The result is an elevator that provides a high uptime and that has a planned lifetime that is twice that of a normal elevator, up to 50 years. The cost over the lifecycle is kept to a minimum by high quality production and advanced technology that helps preserve value. For the customer there is no need to invest upfront for new elevators nor maintenance schemes, costs that can be significant for a large building stock. Both the customers and the company benefit from this and in the end, it provides the same function (with better reliability) and less environmental impact.

Things to watch out for:

It's important to merge research and development and the commercial side. This is often a challenge, at least in large corperations, since they are often big and live separate lives.

Don't forget to think about the value proposition in parallel with product design. This can highlight obstacles as well as opportunities. It can also serve as specification of what research and development should investigate later in order to enhance the value or cut cost.

Be aware of the real environmental benefit. For example, too much of the wrong types of transports in subscription models can eliminate a lot, if not all, of the reduction in environmental impact.

During a pilot, you can do most calculations in excel. Later, when it's time to scale, IT systems often need to be built and tailormade. It is common that this becomes an obstacle for companies that want to grow and it is one reason why many get stuck after the pilot stage.

PaaS models where customers pay regularly (for instance each month) generate revenue streams that are more resilient towards recessions than linear business models. For example, if a customer rents furniture and pays per month, the likelihood to end the contract during a recession is likely quite low whereas the same customer is unlikely to purchase new furniture during a recession.

With kept ownership comes a big challenge: how to finance the capital. There are some solutions here but the most important one is to generate known residual values if you want to keep the products off the balance sheet and let a financier offer you a lease-back, a financier that then take the risk.

Frishammar, J., & Parida, V. (2021). The four fatal mistakes holding back circular business models. MIT Sloan Management Review, 62(3).

ACTIVITY C

Assessing the current state

Read more about the two tools to assess risks for premature obsolescence on page 48-49.

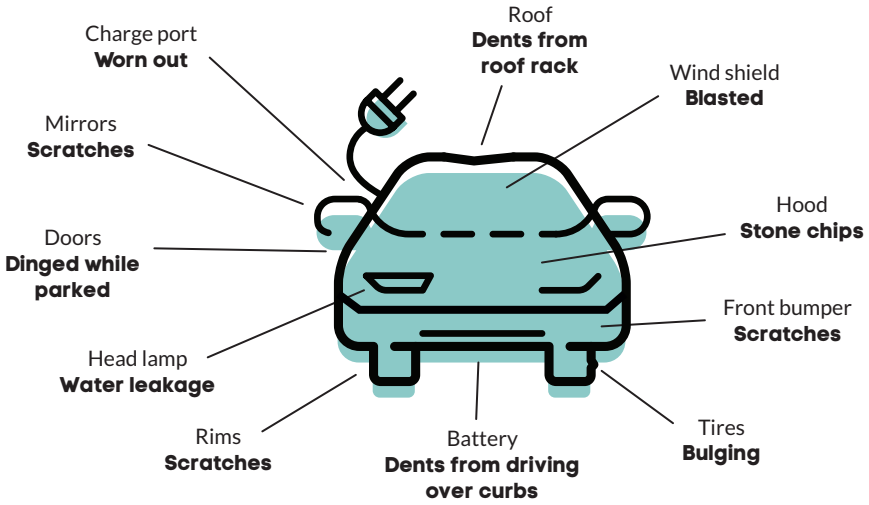
What should you do to make your product fit for a new value proposition built on longevity? By assessing the current state, you will gain an understanding of both the challenges associated to your current product (or perhaps a planned future product or a product offered by your competitors) and what you need to address to make the design fit for you circular value proposition and business model. In this guide, we describe how you can assess your design from three key perspectives: Design – identifying risks for premature product obsolescence; Business – identifying lifecycle costs, and Environmental impact – identifying hotspots. Moreover, we recommend that you compare these assessments to identify the components that are most urgent to address.

Design – Identifying risks for premature product obsolescence

As described on pages 8-9, product obsolescence can be spurred by a single reason or a combination of reasons. What some customers and users may consider to be of low or no value, may be valued by others. When designing for longevity, it is hence essential to first understand the key reasons for people to deem the product obsolete. We suggest that you start off by gathering as much detailed data about the product as possible, such as data from product tests and customer complaints. You want to know what is likely to happen to the product during its lifetime and how the current design meets requirements from customers and users. If the available data is not enough, you can conduct new studies to map how customers use and experience the product. Use the data to also ideate around possible surprises that can occur. Perhaps there are potential risks for failures after several use-cycles, or perhaps the product will become unattractive for customers and users due to new trends.

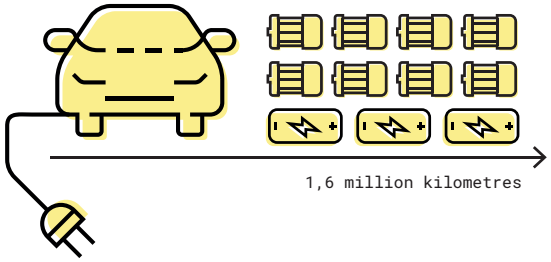
We suggest the following steps when identifying risks for premature product obsolescence:

- Invite competences that has in-depth experience of the product you want to analyse and competences that provide complementary perspectives. Preferably from design, product development, sales, aftermarket, and public affairs, and from your subcontractors (if applicable).
- If possible, analyse a sample product (preferable a used one) to get a better understanding of how aging and usage will affect performance, visual appearance etc.
- Use your vision and use scenario for an extended product lifetime as a lens for the analysis. Combine it with various usage scenarios and defined user typologies relevant for your value proposition. Consider both standard use cases and extreme ones to stress test the products' capabilities to a higher extent.
- Map potential risks that can be expected based on your first vision for extended longevity. Consider all four drivers of obsolescence: technical, functional, aesthetical, and social obsolescence. You can make use of the tool *Drivers of product obsolescence* to map out these risks, and when they might occur.
- Now turn your focus towards current strengths. Does the product have qualities that can help lower previously identified risks for obsolescence? You can use the tool *FAD screening* to assess the product's durability, flexibility and adaptability.
- Identify the risks that will be most challenging given the intended value proposition. Keep these in mind when ideating later on.



Damages of once pristine exterior surfaces of cars can occur in many ways. Based on the current product architecture, small damages can be very costly to repair. Even small scratches, stone chips, and dents can increase business risks for the vehicle owner since repair operations may require significant downtime and costs. Costs for dismantling replacing parts may be significant. It is important to add these to the business calculation, Some components, such as high voltage batteries can require significant time and costs to dismantle and ship to repair hubs. Information from aftermarket operations, such as product warranty issues, common failures, and damages is also valuable when analysing risk for obsolescence.

What if someone drove an electric car more than 500 km per day?



By exploring how extreme users utilise the product, valuable insights can be gained regarding which components that need to be repaired, exchanged, or upgraded, and when. For instance, a previous Tesla owner that drove more than 1,6 million kilometres with a 2013 Model S, had to exchange eight electric motors and three battery packs. Relying solely on regular customer feedback may not suffice to collect such data in time to plan for additional services and availability of spare parts to meet the needs of most customers.

Business – Identifying lifecycle costs

To assess the profit potential of your value proposition, you need to identify all cost items associated to the delivery of your offer – the Total Cost of Ownership (TCO). It's all about mapping the costs required for keeping the products attractive over time.

To get started, take a relevant linear 'as-is' product, ideally a generic product or the bestseller. Map all cost items that occurs over time to keep that product in use and attractive. Be aware, all costs will be the company's costs if a PaaS model is applied. There is no such thing as a lucrative service market anymore. The cost items you want to identify can include costs related to depreciation, service jobs, parts, refurbishment, upgrades, tied capital, and extra services offered. If you want to explore scenarios for significantly increased longevity, it is relevant to conduct new product test studies to learn about the durability and to identify potential new cost items. But estimations will suffice at this stage.

Both controllers and service market teams can be helpful when identifying cost items and estimating numbers. The service market likely has the best overview about what needs to be done and when and what it costs. In general, it is good to involve people from different perspectives at an early stage as it will be helpful later from a change management perspective. The outcome of this TCO analysis can be seen as a specification to research and development regarding the question *Which parts of the design needs to be adjusted to reduce costs?* It is thus a good idea to involve them early on as well.

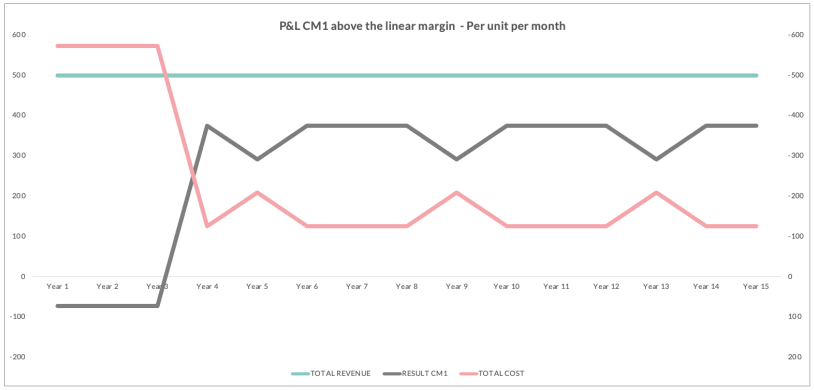
Normally, a product is planned accounting-wise to depreciate in financial value faster than the actual value. That means fairly high cost during the depreciation period, often the first three to five years. After that, the depreciation is done and the product is paid off. However, the cost of keeping the product attractive will increase since it ages but these costs are normally lower than producing a new product. Thus if the willingness-to-pay stays fairly high, the circular model can start being more profitable than the linear model already after a couple of years, and additional usage after this point means new profits.

The following method can be used to quickly get a rough understanding of the profit potential for a value proposition built on a Product-as-a-Service or a take-back model. To ensure that all allocated costs that the current linear product carries are included, an easy 'sell-it-to-yourself'-methodology can be used. Put the retail value of the linear sold product as a cost in your calculation. By doing so, you will have covered the total margin of the existing product (and the current business); if you manage to achieve profit in the circular business model, then the alternative is actually more profitable for the company than the current model of only selling the product once. The method can also be used to explore which variables that affect the profit and to what degree. You can check if it is the interest rate, price, parts or something else that is most crucial.

Want to assess the Total Cost of Ownership for your value proposition? You can make use of the tool *TCO analysis* described on page 50. This tool can also be used to simulate how the potential for profitability may change when the product is designed for longevity and adaptability.

Excluding VAT — The numbers in the first table reflect revenues costs per **month**. Row 19 aggregates the numbers to a yearly figure.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15
Subscription fee/leasing	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Other revenue															
TOTAL REVENUE	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Product cost	-388	-388	-388	0	0	0	0	0	0	0	0	0	0	0	0
Service	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42	-42
Spare parts	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83	-83
Upgrades (X SEK per Y years)					-83				-83				-83		
Cost Y	-60	-60	-60												
Cost Z															
TOTAL COST	**-573**	**-573**	**-573**	**-125**	**-208**	**-125**	**-125**	**-125**	**-208**	**-125**	**-125**	**-125**	**-208**	**-125**	**-125**
RESULT CM1	**-73**	**-73**	**-73**	**375**	**292**	**375**	**375**	**375**	**292**	**375**	**375**	**375**	**292**	**375**	**375**
AGGREGATET TOT CM1	**-877**	**-1 755**	**-2 632**	**1 868**	**5 368**	**9 868**	**14 368**	**18 868**	**22 368**	**26 868**	**31 368**	**35 868**	**39 368**	**43 868**	**48 368**
Units	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**
Yearly increase of units (optional)	0%														
Profit and Loss	-17 549	-17 549	-17 549	90 000	70 000	90 000	90 000	90 000	70 000	90 000	90 000	90 000	70 000	90 000	90 000
Salary admin/field person 50%	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450	-23 450
Cost Y															
Cost Z															
RESULT	**-40 999**	**-40 999**	**-40 999**	**66 550**	**46 550**	**66 550**	**66 550**	**66 550**	**46 550**	**66 550**	**66 550**	**66 550**	**46 550**	**66 550**	**66 550**
AGGREGATED RESULT	**-40 999**	**-81 998**	**-122 996**	**-56 446**	**-9 896**	**56 654**	**123 204**	**189 754**	**236 304**	**302 854**	**369 404**	**435 954**	**482 504**	**549 054**	**615 604**



The table shows an example of the revenue, costs and profitability for a company that offers bike subscriptions (PaaS) instead of selling them linearly. In the first three years the company shows negative returns due to depreciation. After the bikes are depreciated the business model show positive returns.

Environmental impact – Identifying hotspots

When attempting to reduce the environmental impact of a product, it can help to assess the product system and its life-cycle to identify the main impacts and their causes. A hotspot analysis based on life cycle assessment (LCA) data is an effective method to do this. Hotspots in this context can be defined as processes or components with a relatively large contribution to the total impact of an environmental impact indicator, e.g. Global Warming Potential (GWP) indicating the net flow of greenhouse gas emissions (GHGs) from a defined system boundary.

The hotspot analysis can be performed in several iterations dependent on the system boundary and the level of detail in the LCA. The degree of influence specific processes or components have on the total impact diminishes as one goes deeper since it means essentially focusing on smaller and smaller portions of the total impact. Important to remark is that a manufacturing company also has less opportunities to influence impacts associated to processes and components far back in the value chain since they typically have little control over such processes and no possibilities to communicate requirements or discuss potential improvements.

If following the top-down approach, the first iteration would typically be on the lifecycle phases, e.g. production, use, and end-of-life. Although one lifecycle phase may be the most dominant in terms of environmental impact, it can still be relevant to assess all phases since changes in one of them can influence the other ones. If we use a heavy electric truck as an example (see next page), a new design of a component can affect the environmental impacts associated to both the use phase and end-of-life. For instance, by switching to lighter components, the fuel consumption can be reduced and by designing with modularisation in mind, the number of processes required during end-of-life can be minimised.

After assessment of the lifecycle phases, subsequent iterations are required to identify hotspots for the phase(s) with high impact. An assessment of hotspots can be made along the entire value chain, from the production of the entire product to the production of sub-components and materials, and finally the extraction of natural resources. Several iterations may be required to find the root cause of the relatively high environmental impact from a component such as cross members in a chassis. A a truck consists of many components which can make a hotspot analysis overwhelming in terms of the number of processes that need to be evaluated. To get an overview and easily find the hotspots in each iteration it can be helpful to create visualisations, for example pie charts.

How to conduct a hotspot analysis from an environmental perspective?

DEGREE OF INFLUENCE

FIRST LEVEL OF ANALYSIS:

Which lifecycle phase(s) is associated with the most environmental impact?

PRODUCTION → USE → END-OF-LIFE

SECOND ITERATION:

What contributes the most environmental impact for each phase?

For example, in regard to production, assess the impact of different components:

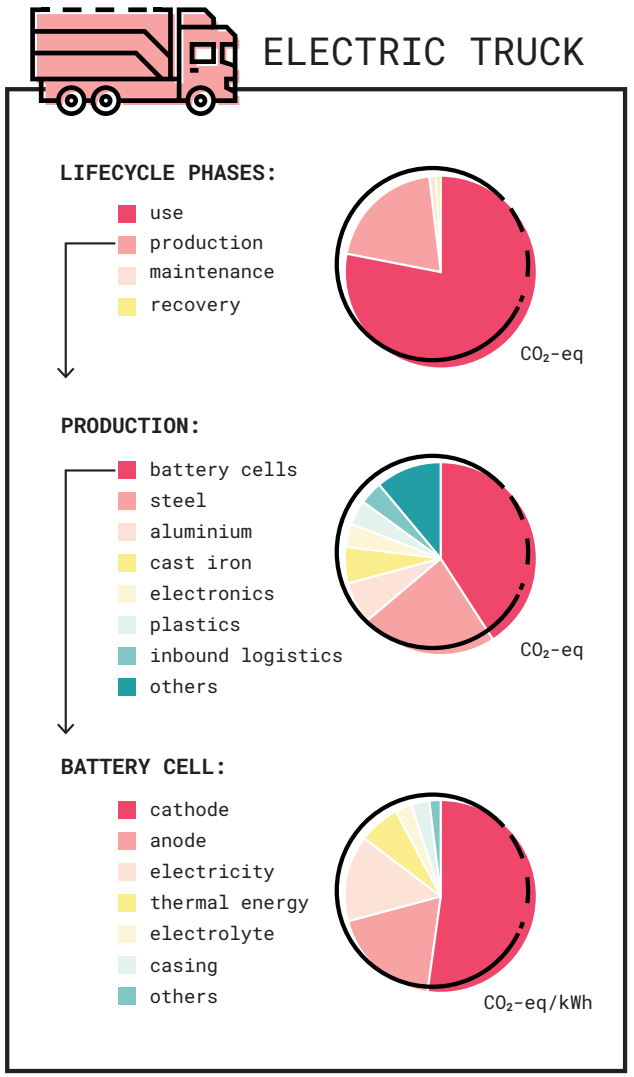
- COMPONENT X
- COMPONENT Y

THIRD ITERATION:

Which are the main impacts along the value chain?

For example, assess the key impacts for a specific component along the entire value chain:

- PRODUCTION OF SUB-COMPONENTS
- PRODUCTION OF MATERIALS
- PRODUCTION OF CONSUMABLES
- EXTRACTION OF NATURAL RESOURCES



A hotspot analysis can help to determine what processes and components that causes the most environmental impact. Such an analysis will be done in several iterations starting with mapping the impacts associated to the main lifecycle phases. The example illustrates data from an analysis assessing impacts from an electric truck.

Comparing assessments using a FAD Heatmap

After you have assessed the current state of the product you have to choose what parts you should focus on when it comes to exploring FAD opportunities. To help with the prioritisation process, you can make a "FAD Heatmap" of the components you find relevant. Based on the outputs from the key aspects discussed in this section (risks for premature obsolescence, lifecycle costs, and environmental hotspots), colour code the components ranging from low impact/risk (lighter colour) to great impact/risk (darker colour). How you categorise what is low to high impact/risk is up to you. As an example, the LCA hotspot categorisation for CO_2 could be based on: i) CO_2 emission per component, ii) CO_2 emission in relation to the component's weight, or iii) CO_2 emissions in relation to the total product weight. After categorising each component across all aspects, you should be able to see which component you should prioritise when exploring FAD opportunities.

"The analysis was really useful for us, it helped us to identify which layers that are most problematic and what we should address. It makes it relevant to think in different ways for skins, organs, and so on."

FAD Heatmap for a laptop

What parts are especially relevant to address when exploring FAD opportunities?

			RISKS FOR PREMATURE PRODUCT OBSOLESCENCE				LIFECYCLE COSTS	ENVIRONMENTAL HOTSPOTS			
Layer-based product architecture	**Part / module**	**Component**	Technical obsolescence	Functional obsolescence	Aesthetical obsolescence	Social obsolescence	Costs	Kg CO2e	Abiotic Resource Depletion - ARD	Substances of Concern - SoC	**Key components to address**
Skin Visible and tactile surfaces	Screen	Display									
	User interface	Keyboard									
Organs Functional components	Storage	HDD/SSD									
		Battery									
		Speakers									
		CPU									
Skeleton Supportive structure		Body									
		PCB									
Metabolism Resource use and associated systems		Power supply unit									
		Cables									
		Charger									
DNA Software and digital information	Digital information	Information about charging cycles									
	Digital information	Information about product history									
	Software	Operating system									
Key effects to address											

This illustrative example shows that a laptop's battery and PCB should be prioritised when exploring FAD opportunities. Both have high environmental impact, high costs, and are at high/medium risk for technical obsolescence and also demonstrate some risk for functional and social obsolescence. Darker colours indicate greater impact/risk.

Read more about the *FAD Heatmap* tool on page 51.

”The tricky thing is that we have so many components and we don’t know what happens to our product during its life. We don’t have all the data to understand and assess everything.”

Designer

Things to watch out for:

For complex products, assessing the current state in detail is time-consuming, but can be done in several iterations. As a first prioritisation, try to identify components that represent the most financial costs and environmental load, as these will affect the TCO the most.

To speed up the process, try to gather as much detailed information about the product from experienced and well-informed people. Try to find extreme users to use as a reference point.

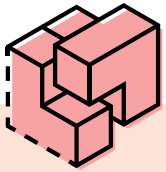
Keeping up a high pace is more important than getting costs exactly right. If no real cost data is available, try to do qualified guesses based on similar products, and then check with experts.

If there are no life cycle assessments for the product available, try to search for assessments of similar products. For many product categories, there are life cycle assessments or environmental product declarations (EPDs) available online that can provide data to work with. You can search for EPDs at https://www.environdec.com/.

If there is an LCA available, make sure that it includes all relevant data for the component you want to analyse. For complex products with thousands of subparts, simplification of some components can be lacking detailed data that can be of importance. If not, complement with rough assumptions.

When working with the Heatmap, assessing components in relation to a layered-based product architecture can sometimes be tricky since some components can be deemed to belong to several layers. For instance, a composite component can represent several layers at the same time. Don´t get stuck trying to figure out which layer a component belongs to, the important thing is to identify the most risky versus less risky components in the product architecture.

If the business case results in too high costs during the first years due to depreciation, explore if a different depreciation time can be used. If you can motivate that your product can be used for longer than the standard three to five years, you can lower your yearly cost by using longer depreciation times. Also consider if value-adding improvements can be used to more accurately reflect the value of the asset and to spread out the cost of those improvements. For example, if an electric vehicle is upgraded with a new (more expensive) battery that offers longer range, its value may increase. Note that accounting rules may vary between countries.



ACTIVITY D

Exploring opportunities for Future Adaptive Design

Read more about tools that can help you explore FAD opportunities on pages 52-54.

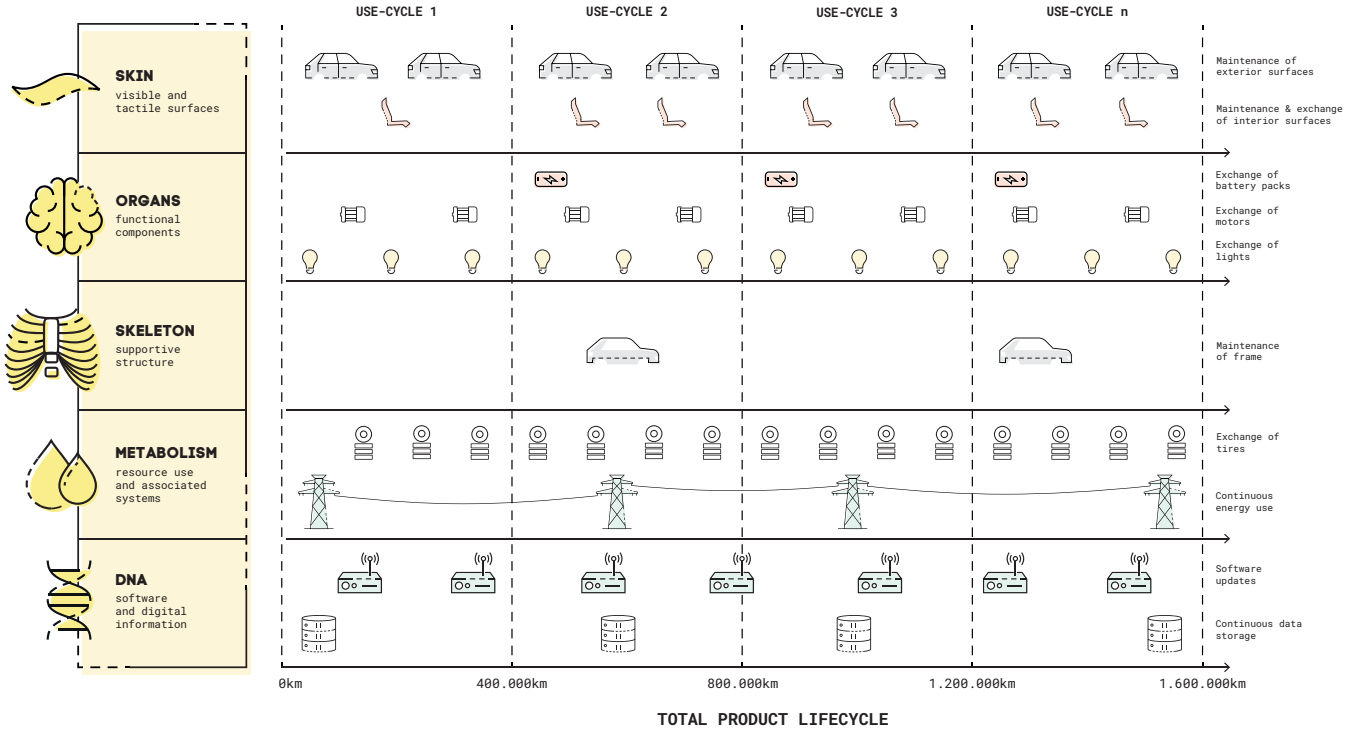
The FAD strategies rest on the notion that products that can be adapted over time, for instance through upgrades, will keep their values and may even in some cases increase their values. Products that can't adapt to changed requirements and user needs will become obsolete since products that lose functional value risk being put idling or scrapped prematurely. In fact, for many commercial and durable products, the pace of technology development and lack of adaptability can make residual values drop rapidly.

To address such risks in the early phases of design, FAD rely on two types of possible mitigating strategies, preventive and curative design strategies described on pages 16-18. Combined, these strategies increase the potential of preventing premature obsolescence either through a product architecture that allows for adaptations over time, or through add-on content and cascading usage that help preserve embedded product values.

We suggest starting off by addressing the components that are most prone to become prematurely obsolete or are associated with high costs or high environmental impact. Other components that may reduce revenues or increase cost in an extended product lifetime scenario can also be relevant to address later on, as well as components that are easy to improve or exchange. Ideate around both short-term and long-term mitigating solutions. Long-term solutions can be major changes in systems, platforms, or to the whole product architecture.

When exploring FAD opportunities, we recommend that you:

- Start by choosing some of the components previously identified as having the highest risks to become premature obsolete, the highest lifecycle costs, and the highest environmental impact. If you have not yet identified these components, you can use make a FAD Heatmap as described on page 30.
- Ideate around opportunities for preventive and curative improvements using the FAD design strategies. The *FAD opportunities canvas and ideation cards* can be helpful during ideation, and the *FAD evaluation matrix* can be used to assess and compare concepts based on FAD design criteria.
- Visualise identified opportunities so they can be discussed in the working group or communicated to other stakeholders such as customers or subcontractors. Structure the opportunities in a way that is meaningful for you, perhaps in relation to the level of complexity or when in time the improvements could be necessary or possible to implement. You can make use of the tool *Lifecycle service planner* to visualise and describe activities through the product's lifecycle.
- Prioritise opportunities and summarise how you aim to make your design adaptive to future requirements, e.g., in a live longer configuration for your product, with stepwise improvements that can steer against the initial vision.



Which lifecycle service activities are needed?

By using the preventive FAD strategy Lifecycle service planning, various longevity scenarios can be envisioned and communicated, including multiple use-cycles with life supporting activities. In this example, an electric car is planned to be used 1.6 million kilometres. Required maintenance, repair, overhaul, and upgrade activities are mapped to provide an overview of the lifecycle. Note that this illustration only exemplifies what could be done and does not represent the current expected lifetime of a car.

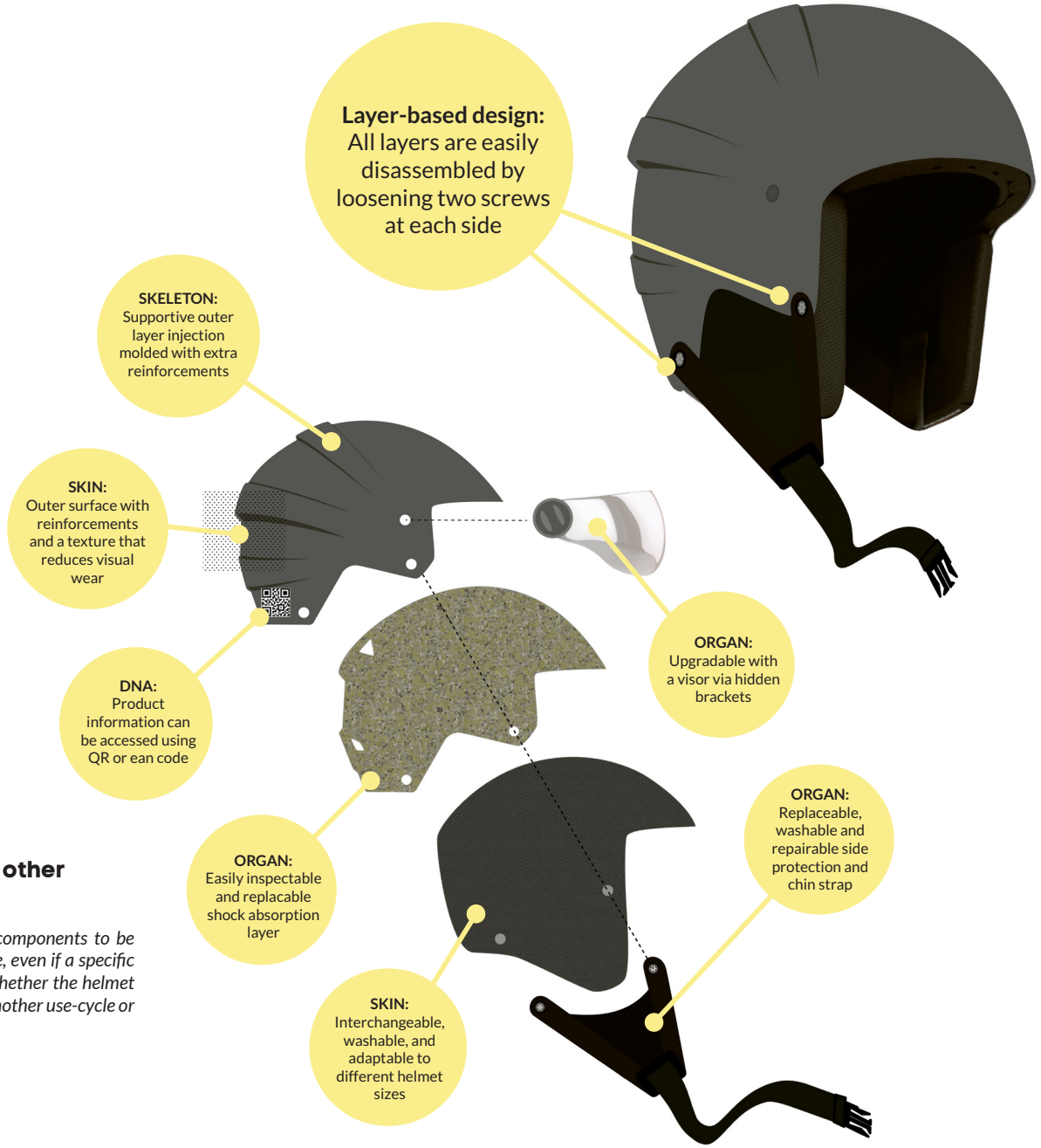
	SKIN	ORGANS	SKELETON	METABOLISM	DNA
	Surface materials, color, touch, feel, and visability Sound and smell	Screen, Data-storage CPU Communication Cooling	Casing Interfaces and connectors	Power supply Energy usage Cables	Software architecture Sensor information
Short-term actions	Using recyclabe ingredients for visable surfaces Adding surface patterns	Screen protection expandable RAM and storage Exchangable and upgradable battery	Using aluminium Exchangable external connectors	Reducing energy consumption Including solar power accessories Repairable power cables	Open software data preconfigured for easy switch between operating systems
Medium-term actions	Improving resolution/visability Less noise without fans Smell options	Upgradable CPU (air cold) Removable fans Faster communication Better camera, sound system	Upgradable lightweight chassie and power adapter	Foldable solar panel for indoor use Upgrading to wireless charging	DIY information about how to build accessories with exchanged components when upgrading
Long-term actions	Add-on foldable solar panel for indoor use Foldable bigger screen	Exchangable components with high environmental load (as CPUs, and batteries) made of bio-based ingredients such as mycel		Only using energy efficcient cloud computing	

What actions should be planned for?

This is a fictious example of an action plan to improve durability, flexibility and adaptability for a modular laptop. Short-term actions could include offering already available components, like protection covers or accessories, and offering user-replaceable parts such as batteries or memory disks to increase product lifespan and reduce electronic waste. Mid-term actions could include redesigning the laptop's outer shell for more robustness, introducing specific adaptive components that can be easily replaced or upgraded by users, and adding more connectivity options for wider device and peripheral connectivity. Long-term actions could include developing a new platform design that is adaptable to future technology trends and user needs.

Product Development Manager

”We have divided the product in parts that can be easily exchanged. We have made sure that the parts that are most likely to change over time have a strong expression and communicates our identity. This way, we can also renew the product’s expression.”



How can a ski helmet be designed so that it is fit for rental or other access-based offers?

A ski helmet could be designed with a layered-based architecture that enables different components to be easily separated and exchanged. This enables reuse of some parts in the product architecture, even if a specific component or layer has been damaged. The outer shell could also be designed to indicate whether the helmet has been exposed to major impacts, which can help providers determine if it can be used for another use-cycle or if it needs to be sent for recycling due to safety reasons.

Legal considerations

In the case of new manufacturing of most products, there are previously established ways to ensure that products meet requirements in terms of safety for humans or safety for the environment. When designing FAD products, you need to identify the legislation surrounding the product and how it affects what you are doing. New issues arise when for example, new ways of verifying the quality of your intended product or new questions related to the content of the product are established (Note: this is important if your product has an environmental labelling). Another question is data accessibility. Accessibility to product information, such as information on available spare parts or instructions for disassembly and assembly, can inherently facilitate reuse.

Legal issues may also arise that you may not think of at first glance. In the case of adaptive products embedded in a commercial building, there are legal challenges to use such products as collateral when financing a PaaS model. Your intended adaptive product may also affect warranties (for what and for how long). Many products of today are also CE-marked. How will your intended adaptive products product be CE-marked? Will a new CE-marking be required? For vehicles, there are lot of regulations in different markets that prevent upgrades if they are deemed to change the vehicle´s "original performance". An example is upgrading a battery in an electric car to a larger range if the overall weight of the vehicle changes. A heavier vehicle may also require different types of brakes. Thus, changing one part in a complex product can affect other parts from a safety perspective. Depending on the market there are also differences regarding who decides if the product is safe to use. In the EU for example an agency decides (i.e., type approval) if a vehicle is safe to use. In the USA, it is the producer who decides if the vehicle is safe enough to put on the market. If the producer puts a vehicle on the market that is not safe enough, there is great risk of high damages being awarded if something goes wrong and if lawsuits are filed. Hence, it may be easier to change a product in some markets, but the risks may also be higher.

Things to watch out for:

Don´t forget to explore opportunities for product design in parallel with the development of the circular value proposition. For instance, high dismantling time means often high manhour costs, but these can be minimised with radical new designs that facilitate assembly/disassembly.

We advise that you make use of the FAD design strategies to explore opportunities. Start off by defining the layered-based product architecture since it determines which adaptations that are enabled over time. In some cases, it can also be good to start with the strategy Lifecycle service planning as it can spur ideas for longevity requirements and adaptations that highlight opportunities for a layered-based product architecture.

Make sure to use your previously defined vision as a lens to explore the need for changes in the product architecture and other opportunities for future adaptive design.

For complex products such as automobiles with 10,000 components, there is an urgent need to prioritise what components to analyse. Otherwise, you may get stuck in the complexity.

Companies running PaaS models could face cost issues if products are "over-refurbished" or if entire components are replaced too often. Sometimes, just good enough condition is just right for the customer and the value proposition. Companies can also address this by adopting a design approach that allows for easy sub-component replacement to minimise replacing entire components. A layer-based architecture strategy can for example, enable replacement of only the "skin" of a bike seat, rather than the entire seat. This approach not only reduces costs but also minimises waste by preserving functional components.

ACTIVITY E

Assessing business cases based on Future Adaptive Design

We suggest two main approaches for assessing a FAD business case: (1) assessing financial and environmental outcomes of design choices, and (2) estimating both financial and environmental costs and benefits through investment analysis. The approaches can be used separately or in combination.

Assessing financial and environmental outcomes of design choices

When designing for adaptability, it is necessary to estimate how design choices may influence short- and long-term costs and benefits, both financially and environmentally. Will the design change pay off? Will initial investments needed in new design and manufacturing be returned by future incomes (or environmental impact reductions)?

There are often many design choices to be made and each choice impacts all others. Finding a reasonable level of future adaptability requires estimating economic and environmental effects of each choice. There are invariably many factors that impact whether the investment (or commitment) to future adaptability pays off or not. For example, component costs might increase initially because of additional product development processes or increased use of expensive materials and production processes, while it may lower the costs in the long run.

When designing for adaptability, it is necessary to estimate how design choices may influence short- and long-term costs and benefits, both financially and environmentally. Will the design change pay off? Will initial investments needed in new design and manufacturing be returned by future incomes (or environmental impact reductions)?

Beyond initial investments, the context and in particular, the business model, drives revenue outcomes, how the customer uses the product, and environmental impact of the product over its lifetime. Longer product lifetimes can result in fewer products sold, which can lead to losses of economics of scale, i.e. less or no bulk discounts when purchasing components from suppliers. In a PaaS model, spare parts and repairs only drive costs, whereas they are a source of revenue in for linear business models. On the other hand, more durable and modular components can result in longer product lifetimes, reduce maintenance, decrease time for repair and increase uptime, and thus raise real and perceived value.

Each design choice related to Future Adaptive Design can thus be considered as having a future value (which can be estimated) based on how much could be gained given a set of current and future circumstances. For example, choosing an extreme-long-life wheel bearing that is both more expensive and that results in more environmental impact during production may pay off both financially and environmentally if the service and use burdens (costs) are offset during the use phase. Such an outcome can be predicted but are naturally not guaranteed.

The same logic can be applied to the choice of an upgradeable wheel bearing (somewhat similar to the extreme-long-life bearing in that it incurs costs but provides future potential benefits). Investing in the option of upgrade by choosing the upgradeable wheel bearing is only worth it if the option to upgrade will be utilised enough to reduce future costs and offset the initial investment. The potential for each component is unique but there are some components that are subject to demand for rapid change during the lifetime.

To determine which FAD design choices will achieve the desired effects and assess whether future adaptive designs are grounded on financial and environmental benefits, it is necessary to consider the concepts of financially and environmentally grounded adaptability. By doing so, insights can be gained that will aid in deciding on an appropriate degree of adaptability and in optimising the design for both financial and environmental benefits.

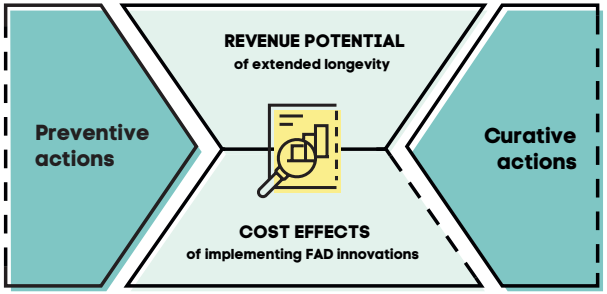
Financially grounded adaptability involves balancing the costs for putting the adaptive product on the market, with potential revenues that can be generated throughout the product lifecycle. By estimating and weighing these factors, a desirable level of adaptability can be determined that will provide future value for a specific CBM.

Environmentally grounded adaptability deals instead with the balance between potential environmental benefits and impacts. Accurately estimating these benefits and impacts requires life cycle assessment data and sometimes, even prototype testing. However, even an exercise in lifecycle thinking using an educated-guess approach can yield a basis for understanding potential environmental costs and benefits.

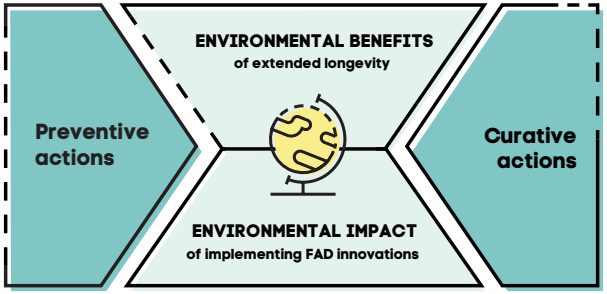
When exploring financially and environmentally grounded adaptability, we recommend that you consider these questions:

- Overall potential: What is the potential to improve financial and environmental effects if product longevity is increased?
- What is the current ratio of use phase impacts versus non-use phase impacts?
- Which parts represent the largest portions of the financial and environmental impact related to production?
- Which parts or modules can be used for longer?
- Which parts need to be adapted and what burdens/investments would be required based on design changes for longevity?

FINANCIALLY GROUNDED ADAPTABILITY

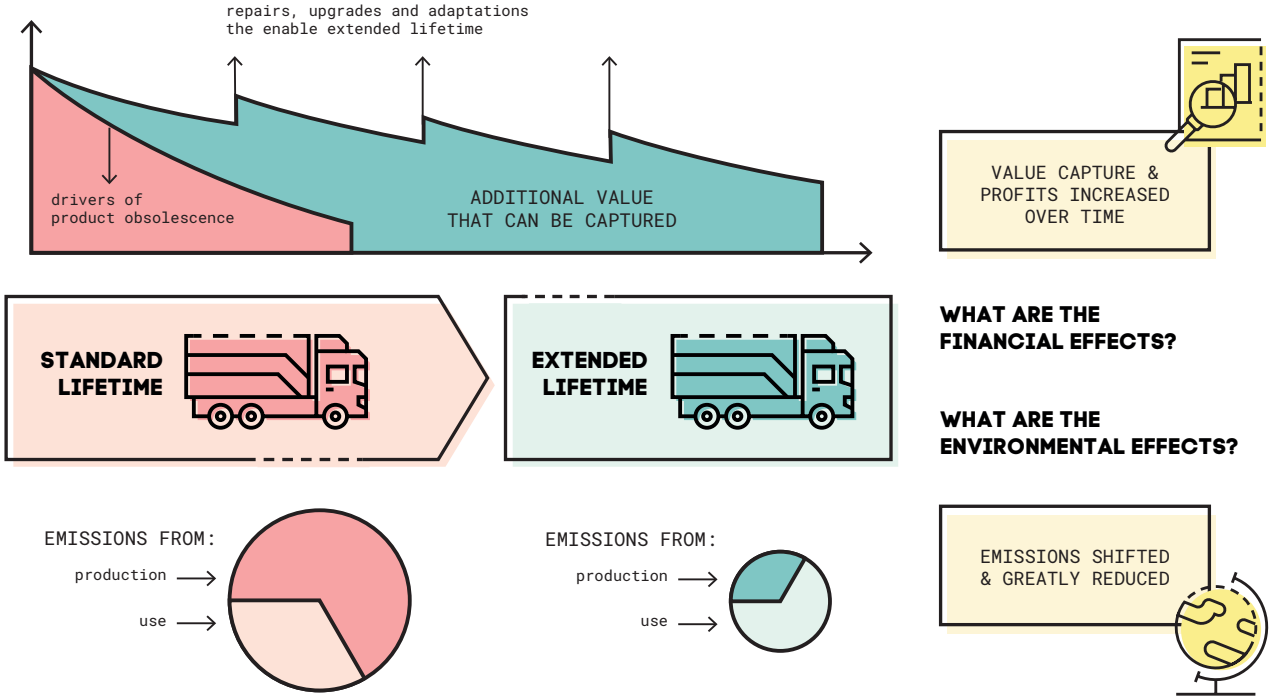


ENVIRONMENTALLY GROUNDED ADAPTABILITY



What financial and environmental effects can be expected from an extended lifetime for an electric truck?

The business case can be defined by the additional value created and is depicted here as the area between the blue-green line and the red line. The red line represents the value loss over a normal lifetime, whereas the blue-green line represents the value of the same product preserved by future adaptive design principles. It reflects how durability, refurbishment, and upgrading can help yield more use (mileage) and more value over time. The environmental impacts from production phases can then be spread out over more use (mileage), thus reducing total emissions and emissions per km, changing the impact from the red pie to the much smaller blue-green pie.



Estimating both financial and environmental costs and benefits through investment analysis

After deciding on what FAD alternatives that are of most interest to analyse further, especially from a profitability aspect, we suggest that you perform an investment analysis of the FAD alternatives compared to the current alternative.

The overall process for the investment analysis includes the seven steps explained below. The analysis expands from a traditional investment analysis by comparing profitability and environmental impact based on a functional unit instead of a fixed production volume, and includes external costs (e.g. CO_2, kilogram material, price risks of input material). Relevant personnel to include when performing the analysis are: design leaders, sustainability experts, business controllers and business developers.

i. Decide on the time frame, which should reflect the expected functional lifetime of the FAD alternative of the product you explore. If you have completed Activity A and/or D you should have explored expected lifetimes for FAD. For example, a lamp producer might expect a longevity lamp to be used for 20 years.

ii. Decide on a functional unit on which an extended longevity product and a current alternative is to be compared. The lamp producer may set the functional unit to illuminating 1 million m² over 20 years.

iii. Outline how extended longevity affects the operations of the company. For example, will it require a change of focus from production to remanufacturing? Will it require a greater consumer service operation? Consider aspects you find relevant.

iv. List all relevant base information and assumptions that the analysis will be based upon. This can include sale prices, labour rates, volume of material used per product, interest rate, downtime cost per hour, etc. For the current product, this information should be available if you have assessed the current state.

v. Gather or estimate revenue and cost information for the product alternatives. For the current product, this information should be available (if you have assessed the current state).

   Revenue may include sale of the product, sale of spare parts, residual value of product components, and new sources of revenue.

   Costs may include costs for Research and Development, Production and Procurement, Distribution and Sales, After Market, Use, and End-of-Life. Costs of relevant risks should be estimated on a best-effort basis to account for risks with linear product design. For example, an extended longevity lamp may reduce the total need for virgin aluminium, which reduces the firm's risk exposure of price variations of aluminium.

vi. If the analysis results in the identification of cost drivers that could be eliminated through design, iterative your vision, design, and the financial calculation. A typical cost driver is labor dependent operations, such as the man hours needed for reparation. The lamp producer may find that it will be expensive to repair a certain component due to an integrated design and may try to shift to a more modular design, where components can be replaced fast, perhaps even by the consumers themselves.

vii. The financial analysis should be complemented by an environmental impact analysis for each alternative. By incorporating the environmental impact, one can compare the alternatives on both total profit and total environmental impact, as well as profit per environmental impact. The environmental impact data could be taken from existing LCAs or best estimates of the alternatives' environmental impact if no LCA is available.

   You can translate the environmental impact into monetary terms if you want to. This can be done by setting a price for CO_2-eq, such as the EU ETS price. It will likely be more difficult to set a price for other environmental factors than CO_2-eq, such as biodiversity loss due to extraction of materials etc., but you can include best estimates.

Want to conduct an investment analysis? Check out the example on the next page and the tool *FAD investment analysis* described on page 55.

What does a FAD investment analysis look like?

This table shows a simplified example of an investment analysis comparing the financial and environmental results between a linear product and a FAD alternative of the linear product. We expect that there may be differences in volumes produced between a linear product and a FAD product and it is therefore important to measure the impact both in total and per functional unit (see step ii of the investment analysis).

	20 year profit & loss (€)	20 year environmental impact (kg)	P&L per functional unit	Environmental impact per functional unit
Current luminaries	366 899	12 000 000	0,37	12
Luminaries with future adaptive design	414 573	5 000 000	0,41	5

Base information	Current alternative	FAD alternative	Comment
Functional unit (illuminated square meters)	1 000 000	1 000 000	Over 20 years
Needed units to illuminate 1 000 000 sqm (units)	100 000	100 000	Active units per year
Sale price (€/unit)	15	25	
Production cost (€/unit)	5	15	Equipment, material, assembly
Expected usage per year (hours)	4 380	4 380	
Expected lifetime (hours)	43 800	87 600	
Total hours illuminated over 20 years	87 600	87 600	12h per day * 365 days per year * 20 years
Required number of units for the 20 year period	200 000	100 000	(Total hours illuminated / lifetime per unit) * active units per year
Labour rate (€/hour)	50	50	
Labour time repair (hours)	1	0,1	Per year and unit
Risk of 100% price increase of raw materials after 10 years	5%	5%	
CO2e per unit (CO2e)	30	50	From LCA or best estimate for lifecycle CO2e
Overhead (% of production cost)	15%	15%	
Discount rate (%)	5%	5%	Often weighted average cost of capital (WACC)
Residual value of material at end-of-life (% of production cost)	2%	7%	

Current luminaries

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenue potential																				
Sale	1 500 000	...	...	...	...	...	...	...	...	1 500 000	...	...	...	...	...	...	...	...	...	...
Rest value		...	...	...	...	...	...	...	...		...	...	...	...	...	...	...	...	...	10 000
Costs																				
Production cost	500 000	...	...	...	...	...	...	...	...	500 000	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
P&L (present value)	**225 000**	...	...	...	...	...	...	...	...	**138 130**	...	...	...	...	...	...	...	...	...	**3 769**
CO2e (kg)	6 000 000	...	...	...	...	...	...	...	...	6 000 000	...	...	...	...	...	...	...	...	...	...

Luminaries with future adaptive design

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Revenue potential																				
Sale	2 500 000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Rest value		...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	105 000
Costs																				
Production cost	1 500 000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
P&L (present value)	**375 000**	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	**39 573**
CO2e (kg)	5 000 000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Things to watch out for:

We often see that companies work in silos and product design and business development work in two separate work streams. We want to stress the importance of working iteratively with development of the product and the business model since they must go hand in hand. The business case assessment and methods described in this section can be seen as a final screening for a product design alternative: go, or no-go.

Circular business models often entail a shift in focus, from operations in production to maintenance and refurbishment. From a current state perspective, it is common that maintenance is more labour-intensive than production, resulting in higher costs of operations. If the investment analysis shows that maintenance for a FAD solution is costly, this insight should be used as input to the design process. It will be necessary to try to develop new solutions which can reduce labour intensity in the maintenance process. Note that just as a change in operational focus may lead to increasing costs of post-production operations, it can also reduce costs for operations in production. Hence, it is important to question both what costs the FAD solution will create and alleviate.

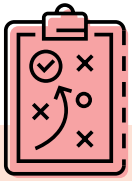
Furthermore, when identifying external costs, you should not forget to identify risks of maintaining the status-quo. For example, if your product is dependent on virgin resources, you are exposed to price variation risks which may be significant as resources become more scarce. There is also an opportunity to critically review market movements and changing customer demands. Can you assume that revenues from current products and offers will increase/stay the same in the future?

Chief Engineer

”Cost engineers always want to push the price down, so does top management. To change the logic, top management needs to be convinced and change this logic.”

”For us, it is challenging to balance the business model and the target price for components. Designs that increase the target price are often rejected.”

Chief Designer



ACTIVITY F

Identifying organisational change required to succeed

It is crucial to get an understanding of how new FAD solutions and circular business models influence the current organisation. The gap between the current business and the demands of the new business determine the amount of change management efforts needed in the organisation. An adjustment of the existing business set-up is easier to implement than a radical and disruptive business model, which requires new roles and competences. Therefore, it is common in larger organisations with more complex product to introduce changes stepwise.

The introduction of an adaptive product and a new circular business model will have an impact on several dimensions of your organisation's dominant business logic, such as: organisational structure and objectives, processes and systems, competence and skillset, culture and mindset, and incentive models and reward systems.

When exploring the need for changes in your organisation, we recommend that you consider potential changes in regard to Research and Development, Production and Procurement, and Sales and Services.

Research and Development

- Changes may be needed to better support design processes. For instance, product specifications for durability and upgradability are most often based on the current business logic. Such specifications will hence need to be adjusted when shifting to a circular business logic.
- FAD requires the selection of materials that are durable, sustainable, and socially responsible. New competences regarding selecting materials and processes that support sustainability while maintaining product quality and longevity may be necessary.
- Longer product lifetimes may require extensive product testing, with needs for new product testing facilities and processes to ensure that products meet new longevity criteria.
- FAD requires a high level of expertise of how the product is used and which services that are needed over the course of its lifetime. To gain such insight, more in-depth customer dialogues, field observations, and customer clinics may be required, not only for new products but also used ones.

Production and Procurement

- FAD requires changes in manufacturing processes to ensure that products are built to last and are easy to service and upgrade. This may involve using higher quality materials, incorporating features that enhance durability, and implementing quality control measures to ensure that products are easy to upgrade.
- Procurement must develop new procurement criteria that prioritise durability, reliability, and sustainability over short-term cost savings. This must be visible in the target prices for components.
- A shift from a traditional linear model of production to a circular model may involve developing new partnerships with suppliers and recyclers, as well as implementing new processes for collecting and refurbishing products at the end of their useful life. For instance, building internal capabilities or collaborations for remanufacturing.
- Applying FAD when developing complex products will require close collaboration with suppliers to ensure that their organisations are also designing with FAD in mind.

Sales and Services

- Organisations must shift to a customer-centric approach to sales, focusing on building relationships with customers and understanding their long-term needs and priorities.
- Since FAD can spur a shift from a traditional revenue model based on transactional sales to a PaaS revenue model, organisations must embrace new strategies to capture value. Such strategies may include capturing continuing revenue streams, such as offering maintenance and repair services, and developing new accessories and upgrades.
- If products are designed to last longer and are easier to service, the number of service hours will naturally decrease. This could potentially lead to smaller service workshops, or that they shift in focus to include also other services such as repurposing, which can take over some of the tasks traditionally assigned to manufacturing.

Chief Designer

”We must change our way of working with components. We need to accept a higher cost per component, until now, we have optimised for linear flows. We need to change, otherwise our designs will not work for circular business models.”

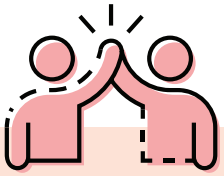
Things to watch out for:

Future Adaptive Design requires a shift in focus from traditional linear volume-based production to a focus on circularity that prioritises longevity. Companies will benefit from taking a lifecycle approach to product and fleet design and consider the entire product and fleet lifecycle from raw materials to upgrades, and end-of-life.

FAD will require that research and development needs to argue for cost-benefit analyses to ensure that design proposals supporting longevity can outweigh the initial costs.

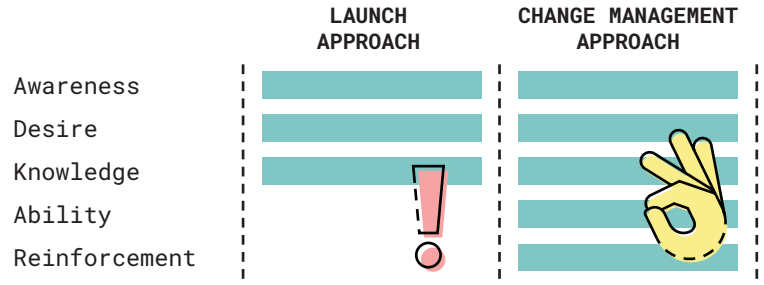
Testing products designed for longer lifetimes can e.g., require more personnel working around the clock.

Incentives and reward systems for the salesforce must be aligned so that selling circular offerings give the same or increased benefits as selling traditional products.



ACTIVITY G

Building capabilities for successful market introduction



Launch and Change Management approaches have similar activities regarding creating awareness, desire and providing knowledge through training. When for example a new business model is introduced, it might not be enough to just launch the new service, business model or product, you also need to work with ability and reinforcement. The ADKAR model was developed by Jeff Hiatt after studying the change patterns of more than 700 organisations.

When introducing new products and services to the market, a product launch is the most common approach. The primary goal of a product launch is to create awareness and generate desire in the commercial distribution network and among customers to drive sales and achieve business objectives. A product launch typically involves the following activities:

- **Creating awareness** through promotion of the product/service to the target groups with launch events, advertising, press releases, articles, and brochures.
- **Creating desire** by communicating the benefits of the product with case studies, testimonials, and social proof, or leveraging influencers or a sense of exclusivity by offering early access or limited-edition versions to a selected group of customers.
- **Building knowledge** by training customers and sales teams with the knowledge and resources needed to use, promote, and sell the product.

However, when introducing new adaptive products and new business models, change management is required both to organise individuals in your commercial organisation and among the customers. The change management method ADKAR advocates that organisations support such changes by working with Awareness, Desire, Knowledge, Ability, and Reinforcement. ADKAR highlights that it is not enough to launch a new offer by creating awareness, desire, and training. People must also have the ability to change, and changes must be reinforced in the organisations to that it can be sustained over time.

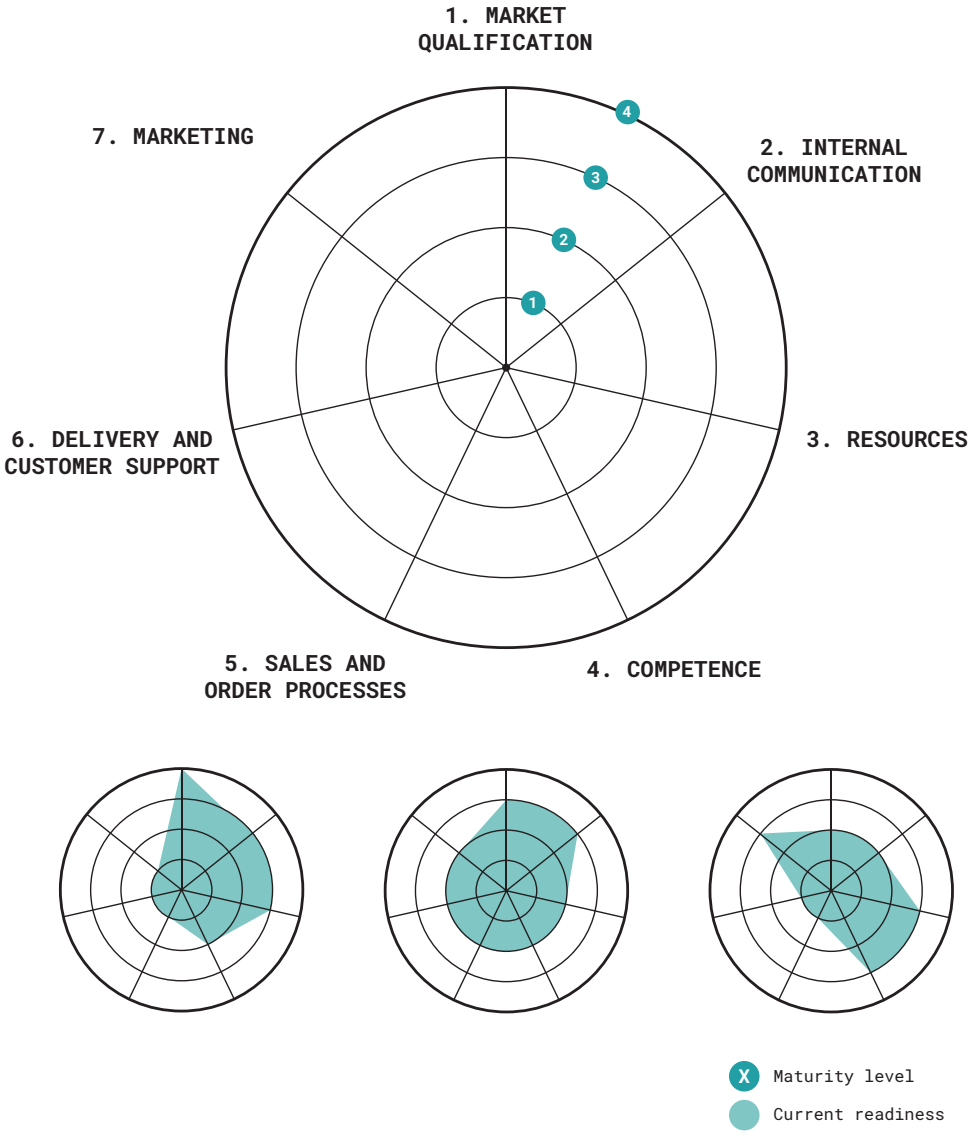
- **Increasing ability** includes supporting hands on practice, providing process support, and removing obstacles that prevent people from delivering the change. For example, if a company aims to offer adaptive products through a new PaaS business model, the salesmen do not only need competence about the new product and offer but also be confident that it delivers the stated values. Also, financial incentives in the salesforce need to be in place, motivating sales of new offerings. To build confidence requires training but also experience. Without the ability to make the change, people will become frustrated, resistant, or unable to adopt new ways of working suitable for the new offer. This creates an obstacle to success.
- **Increasing reinforcement** is important because it helps to prevent the introduction of the new product from becoming a temporary or isolated launch or training event. Reinforcement ensures that the change is sustained over the long term and that people do not revert to old ways of working. Examples of reinforcement are ongoing communication and training, incentive programs, and recognition for those who adopt necessary changes.

The introduction of a new adaptive product and a circular business model can fail for a variety of reasons, such as lack of market research, poor understanding of customer needs, or inadequate user experience. Even if a product is well-designed and meets customer needs, it may fail if your sales organisation is unable to execute the new business model.

Measuring and implementing the ability to execute a new business model is key for adaptive products since they are usually coupled with business models that deviate from the established ones. The Commercial Readiness Level framework considers key factors that influences your company's ability to execute a business model. It helps your organisation to measure the current maturity level and identify activities needed to close the gaps in a specific market.

The key factors that influence the ability to execute a business model in a sales area are:

1. **Market qualification** – Market qualification is the process of evaluating the market to determine whether there is a viable opportunity. Qualification criteria can be, infrastructure requirements, technical certification, market potential, and competitive landscape.
2. **Internal communication** – When a market has been selected, key stakeholders such as sales director, account managers and local champions needs to be informed about the introduction and the change management program.
3. **Resources** – With the support from key stakeholders, resources can be assigned to roles required to make the business model executable.
4. **Competence** – Assigned resources need to be trained to build both competence and confidence. Confidence is created through practice in a supportive environment.
5. **Sales and order processes** – Processes like sales and order handling need to be in place to execute your business.
6. **Delivery and customer support** – If the sales team can sell but key processes like delivery, installation, onboarding, and support is not working, your business will not be sustainable over time. Potential rumors in the organisation about the failure will also decrease the willingness to adopt changes in other markets.
7. **Marketing** – Local marketing material needs to be produced as a complement to central marketing material and campaigns.



A company´s ability to execute a circular business model can be mapped using the Commercial Readiness Level Framework in which the maturity levels for key factors are assessed. By mapping the current maturity levels, opportunities for improvements can be identified.

	MARKET QUALIFICATION	INTERNAL COMMUNICATION	RESOURCES	COMPETENCE	SALES AND ORDER PROCESSES	DELIVERY AND CUSTOMER SUPPORT	MARKETING
Maturity Level 1	Market potential assessed	Market specific communication plan created	Resource plan agreed upon	Competence level assessed	Leads process executable	Installation and delivery process	Local marketing plan established
Maturity Level 2	Required infrastructure checked	Sales Area Management Team Informed and committed	Roles assigned to temporary team	Training and practice plan in place	Sales and quotation process executable	Onboarding executable	Central material translated
Maturity Level 3	Legal requirements such as certification checked	Key stakeholders informed	Ongoing recruitments to fill the gaps	Training conducted	Order handling process executable	Customer support executable	Market specific material produced
Maturity Level 4	Market specific competitor analysis conducted	Kick-off with the initial market conducted	Permanent staff & team in place	Practice or pilots done	Invoicing process executable	Customer success management in place	Offer launched on the market

In the table, you find an example of how you can measure the commercial readiness in your sales organisation in a specific market. Successfully introducing a new offer that deviates from the established business model, requires change and learning on an individual level. Therefore, a stepwise approach is recommended where you start with the most promising markets, concentrate your efforts on them, and build your success stepwise.

Things to watch out for:

Business model innovation processes pose different challenges to a company's top management and organisation. When larger changes are required, it is advised that top management are deeply involved in the decision-making to ensure alignment and rooting. For smaller incremental changes that do not challenge the dominant business logic, top management only need to monitor progress and safeguard against risky innovations. With modular changes, the role of top management is primarily to sponsor and to consider turning the new business model into a spin-off in a separate unit. Radical design changes with modifications to most building blocks may pose a bigger threat to the existing business model and the whole organisation and can also require substantial organisational changes. Here, top management needs to take on the role of business model architects.

If there are difficulties to get commitment from top management, or if you get stuck, consider iterating the value proposition or finding more examples from other industries that can be relevant as benchmark. You can also try to iterate through new customers dialogues, and assess the willingness-to-pay, as this may spark the interest of top management and get the process back on track.

Make sure that you build a company culture that provides psychological safety. This is key for any organisation to ensure that employees dare to think differently and feel confident enough to challenge the existing logic and explore new avenues.

III. METHODS AND TOOLS FOR FUTURE ADAPTIVE DESIGN

Access all FAD tools:

Want to start working with Future Adaptive Design and try out the methods and tool described in this guide? You can find them on www.ri.se. under the expertise *Future adaptive design for a circular economy*.

The Future Adaptive Design toolbox includes:

- Circular vision template
- Drivers of product obsolescence
- FAD screening
- TCO analysis
- FAD heatmap
- FAD opportunities canvas and ideation cards
- FAD evaluation matrix
- Lifecycle service planner
- FAD investment analysis

The following section presents a set of nine hands-on methods and tools that have been designed to aid FAD-related activities in development processes without requiring extensive pre-knowledge. The tools have been developed though iterative work with several companies across different branches as a response to the lack of available tools suitable for business developers and designers that want to work with FAD. While there are already well-established tools available related to activities C and E, such as the value proposition canvas, total cost of ownership calculations, and life cycle assessment, the tools presented here focus on additional issues that needs to be addressed when working with Future Adaptive Design. The tools represent a starting point, and we recommend that you consider and use also other methods and tools when needed.

Circular vision template

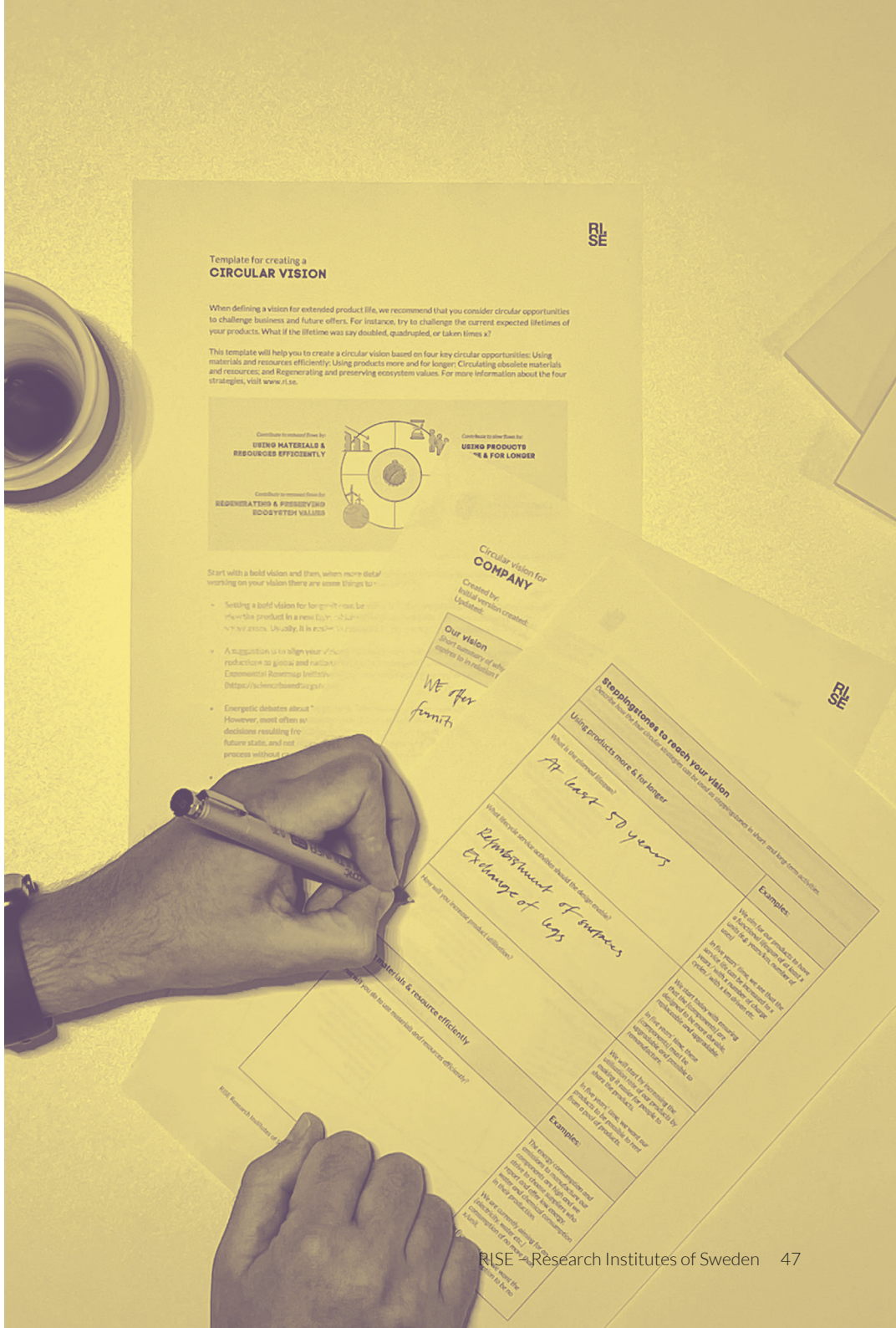
This template can be used to create a comprehensive vision for longevity that covers all circular strategies, including slowing, reducing, closing, and regenerating material and resource flows. By using this tool, companies can develop a first clear vision and strategy for achieving a higher degree of circularity, with a primary focus on product longevity.

How to use this tool

The template is designed to be used in workshops with a multifunctional group in the company aiming to set long-term circularity goals. It starts with defining an overall company vision and breaking it down into stepping stones for the short and long term. One suggestion is to do a first round, and then gradually develop the vision as more information become available.

Preparations

Before using the template, it is suggested to review existing vision and strategy documents related to sustainability and circularity to identify areas for improvement. Additionally, companies can look to other industry leaders for inspiration and use resources like the Exponential Roadmap Initiative and Science-Based Targets to set ambitious targets. Some firms have also set moonshot goals for their product to achieve zero emissions or to even become regenerative, or to contribute with more positive impacts than they generate.



Drivers of product obsolescence

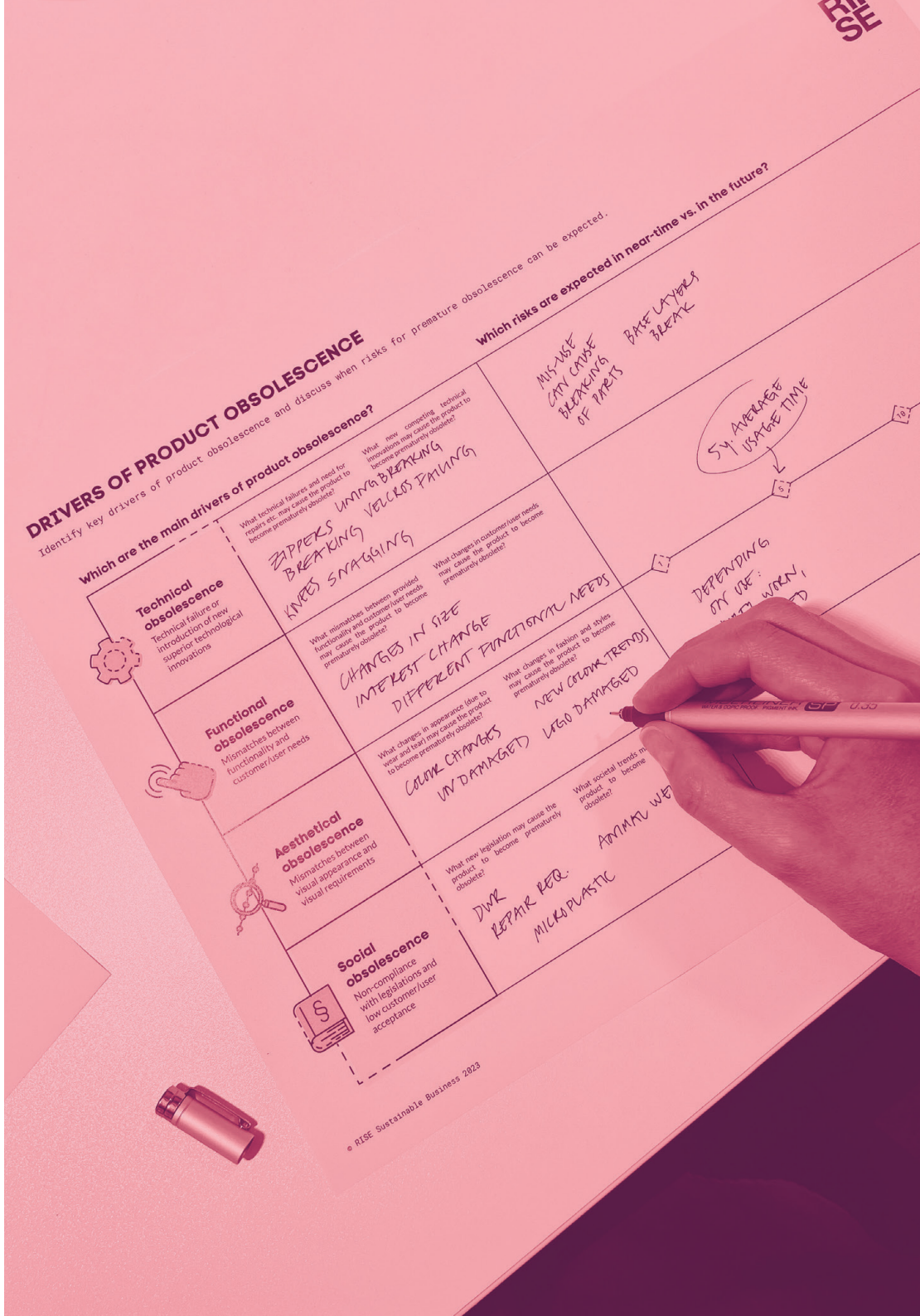
This canvas helps you to explore potential risks for premature obsolescence. It differentiates between the four main drivers of obsolescence: technical, functional, aesthetical, and social obsolescence. With the canvas, you can also make note of when the risks can be expected in relation to the product's lifecycle.

How to use this tool

Start off by considering risks in relation to all four drivers of obsolescence. Make use of the trigger questions to broaden your mind. Once you have identified a set of important risks, consider when they are most probable to occur throughout the lifecycle.

Preparations

If possible, keep a sample product (preferable a used one, or even several) close-by to get a better understanding of how aging and usage has affected its performance, appearance and so on. If data is available regarding common failures and other negative customer experiences, we recommend that you go through this data beforehand, since this will help you to determine which risks are more probable, and when they commonly lead to premature obsolescence.



FAD screening

This excel-based tool helps you to assess how well an existing product can resist obsolescence based on its durability, flexibility, and adaptability. The tool can also be used to identify opportunities to reduce the risks of premature obsolescence and to set requirements for future concept development. The tool consists of a set of checklists that highlights key issues related to the four buildings blocks and the four drivers of premature obsolescence.

How to use this tool

Use the checklists to assess how well your design can adapt to future requirements and resist obsolescence. Once you have completed the assessment, you can have a look at the summary sheet and identify how you can make your design more adaptive to future uncertainties to reduce the risks of premature obsolescence. You can carry out the assessment in one go or iterate your assessment over time in case you need to gather data or other information to be able to answer all assessment questions.

Preparations

Before starting the assessment, gather as much information as possible about the product that you want to assess. You can go through the checklists beforehand to get a better understanding for what type of information that is required to complete the assessment.

TCO analysis

This excel-based tool enables a quick glance of what the profitability could look like for a linear product offered through a PaaS or take back business model. It can also be used for more detailed calculations.

How to use this tool

Use the linear retail price as a cost in the calculation. This way, the existing linear margin is covered and if the tool generates figures in the black, then your circular offer is a more profitable way to go (since it provides extra profit on top of the existing linear business). You can test different price levels, add additional costs, and explore implications for profitability. For instance, profitability simulations can be made for different designs with varying costs. The tool will show which cost items that eat most of the margin, which can provide valuable input to design specifications later on.

Preparations

Before starting the calculation, gather as much information as possible about costs related to the product.

FAD heatmap

This excel-based matrix helps you to get an overview of a product's most problematic components regarding the main risks for premature obsolescence, high financial costs, and large environmental impacts. The matrix is extra helpful when working with complex products since it can aid identification and prioritisation of the key components in need of improvements.

How to use this tool

Use the matrix to summarise your insights regarding what risks for premature obsolescence, financial costs, and environmental impacts that are associated to the product's components. We recommend that you list and describe the components in relation a layer-based product architecture, since components in one layer can share similar risks for product obsolescence and costs. For components that may belong to multiple layers (for instance, the body of a laptop computer that can be viewed both as the skin and skeleton), list them under the layer you find most relevant.

Preparations

To be able to create a heatmap, you need to have identified which risks for premature obsolescence that are associated to key components, which costs that the components will give rise to through the lifecycle, and environmental impacts associated to the components.

FAD opportunities canvas and ideation cards

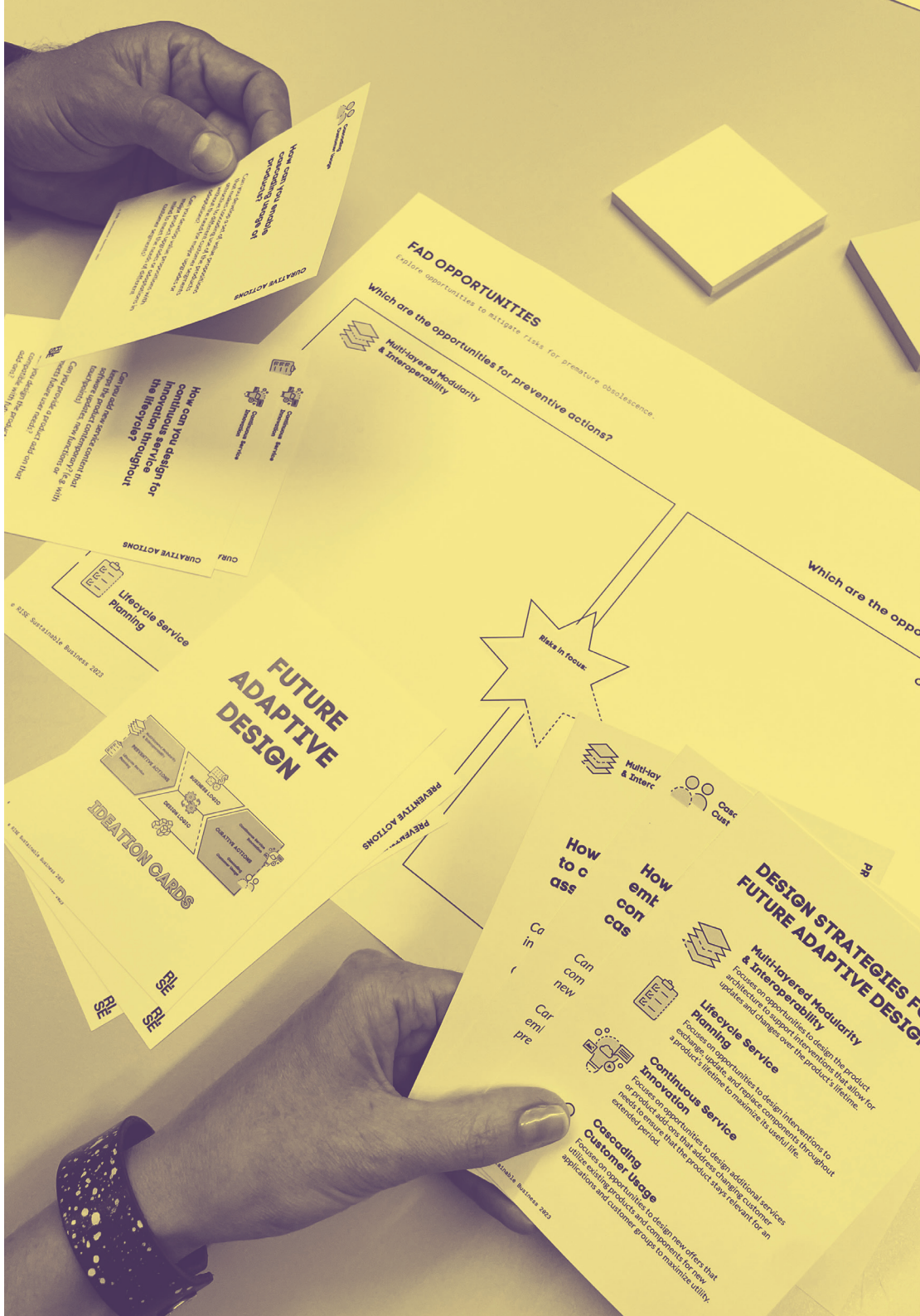
The canvas and ideation cards provide a structure for exploring FAD opportunities and possible mitigating actions based on previously prioritised risks. Strategies for both preventive and curative actions are highlighted, which can contribute to making products valued for longer.

How to use these tools

Use the canvas and cards in ideation sessions to spur creativity. You can address a complete product or focus on the most relevant components based on previous assessments. Use the cards as triggers or a checklist of aspects to consider. Document ideas on the canvas. Focus on one key risk for obsolescence at a time or address several.

Preparations

To make the most of ideation sessions, we recommend that you structure your ideation around previously identified risks for premature obsolescence.



FAD evaluation matrix

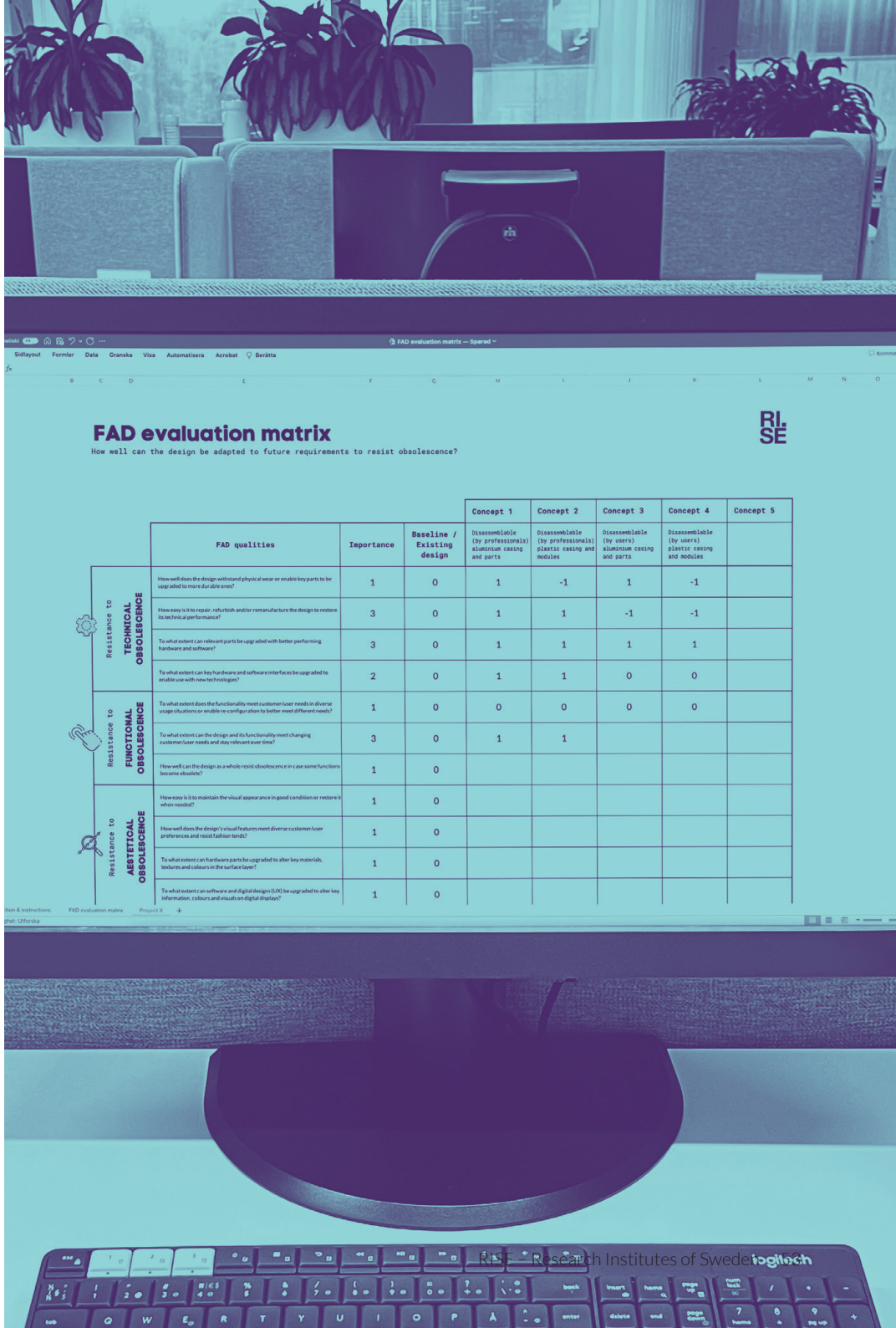
This excel-based matrix helps you to assess how well different concepts can potentially resist technical, functional, aesthetical, and social obsolescence. It helps you to identify which concepts that are better adapted to meet future requirements and evaluate them in relation to a current design. You can also use the matrix to compare a set of existing products.

How to use this tool

Decide on the FAD concepts that you want to assess. Consider how well each concept may resist technical, functional, aesthetical, and social obsolescence and assign scores to each one. You can add scores for an existing product (the baseline) and also rank which FAD qualities you consider especially important based on the type of product. The matrix summarises the scores so that you can identify the concept(s) with most potential.

Preparations

Before using this matrix, you need to have a set of FAD concepts (or existing designs) that you wish to compare.



Lifecycle service planner

The Lifecycle service planner canvas helps you to map probable service activities throughout a product's lifecycle. Relevant activities may include: maintenance, repairs, exchange of components, and upgrades. The overview will help you to better understand the change pace for different components and what type of services your customers may require and how often.

How to use this tool

Use the canvas to consider service activities in relation to key components. We recommend that you list key components in relation a layer-based product architecture, since components in one layer may have a similar pace of change. Make note of how long the expected total product lifecycle is and whether the lifecycle consists of few or many use-cycles. Consider if the service activities are independent of or related to the start/end of the product's lifecycle and/or use-cycles.

Preparations

If possible, gather data on probable activities based on current designs that can serve as a basis for mapping out service activities for your future design and value proposition.

FAD investment analysis

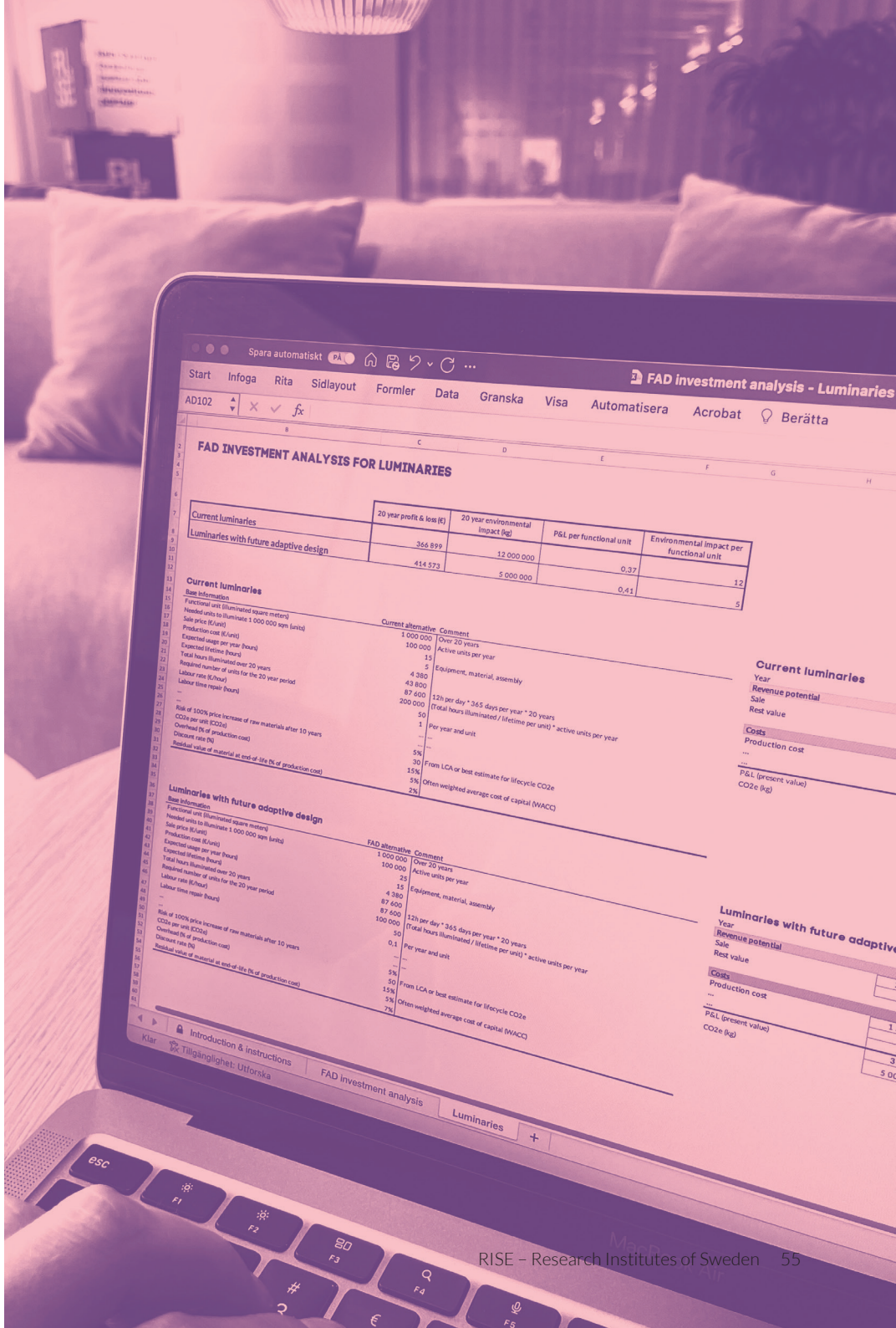
This excel-based tool can be used for two purposes. Firstly, it can be used to identify how product design alternatives vary in revenue and cost structure, as well as to identify key cost drivers and risks. This will help you to explore how to mitigate costs with alternative designs in an iterative design-business case development process. Secondly, it can be used as decision support for management/board/investors to decide on new business models. Compared to the tool TCO analysis, this tool enables a more detailed analysis which also capture external effects.

How to use this tool

The overall process for the investment analysis includes seven steps described in detail on page 38.

Preparations

To carry out the investment analysis, some input is needed regarding the value proposition and expected financial costs etc. Moreover, historical revenue and cost data are helpful to prepare in advance.

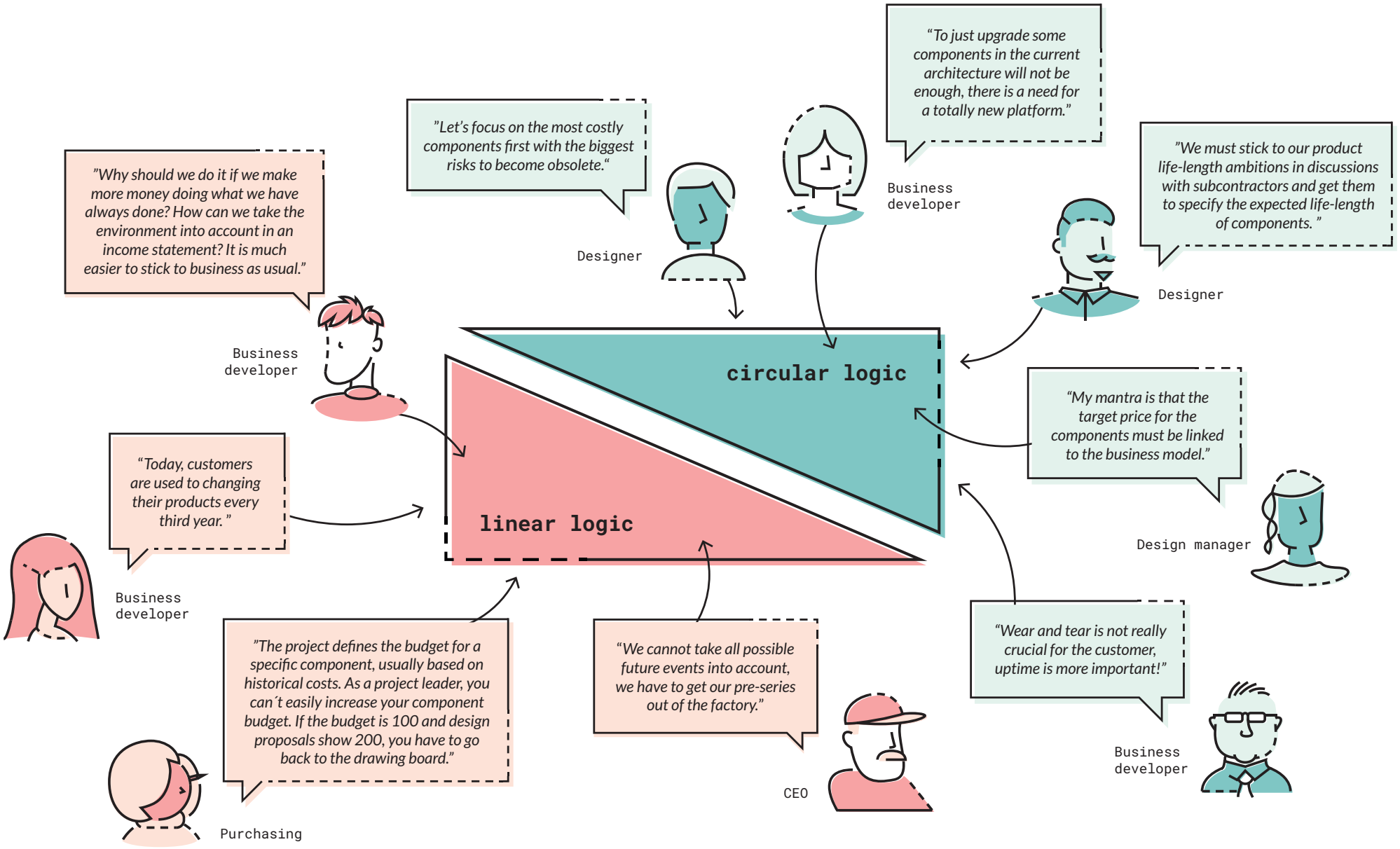


IV. SUMMARY AND OUTLOOK

As described throughout this guide, FAD points to opportunities for designing circular products, services, and business models to radically reduce environmental impact while at the same time retain or increase embedded value(s). By understanding risks for premature obsolescence, and designing for durability, flexibility and adaptability, companies can increase the potential that a product is kept in use and appreciated for longer.

Future Adaptive Design challenges the current dominant linear logic

Today, most companies' business logic is based on a linear mindset. Since the concept of FAD challenges the dominant linear logic, employees at such organisations can experience lock-in effects and feel restricted when trying to explore opportunities for FAD and CBMs. To successfully embrace FAD, companies must start to question their established design and business logics and explore new logics for creating and embedding product values long-term.


"Why should we do it if we make more money doing what we have always done? How can we take the environment into account in an income statement? It is much easier to stick to business as usual."
Business developer
"Let's focus on the most costly components first with the biggest risks to become obsolete."
Designer
"To just upgrade some components in the current architecture will not be enough, there is a need for a totally new platform."
Business developer
"We must stick to our product life-length ambitions in discussions with subcontractors and get them to specify the expected life-length of components."
Designer
circular logic
linear logic
"My mantra is that the target price for the components must be linked to the business model."
Design manager
"Today, customers are used to changing their products every third year."
Business developer
"The project defines the budget for a specific component, usually based on historical costs. As a project leader, you can´t easily increase your component budget. If the budget is 100 and design proposals show 200, you have to go back to the drawing board."
Purchasing
"We cannot take all possible future events into account, we have to get our pre-series out of the factory."
CEO
"Wear and tear is not really crucial for the customer, uptime is more important!"
Business developer

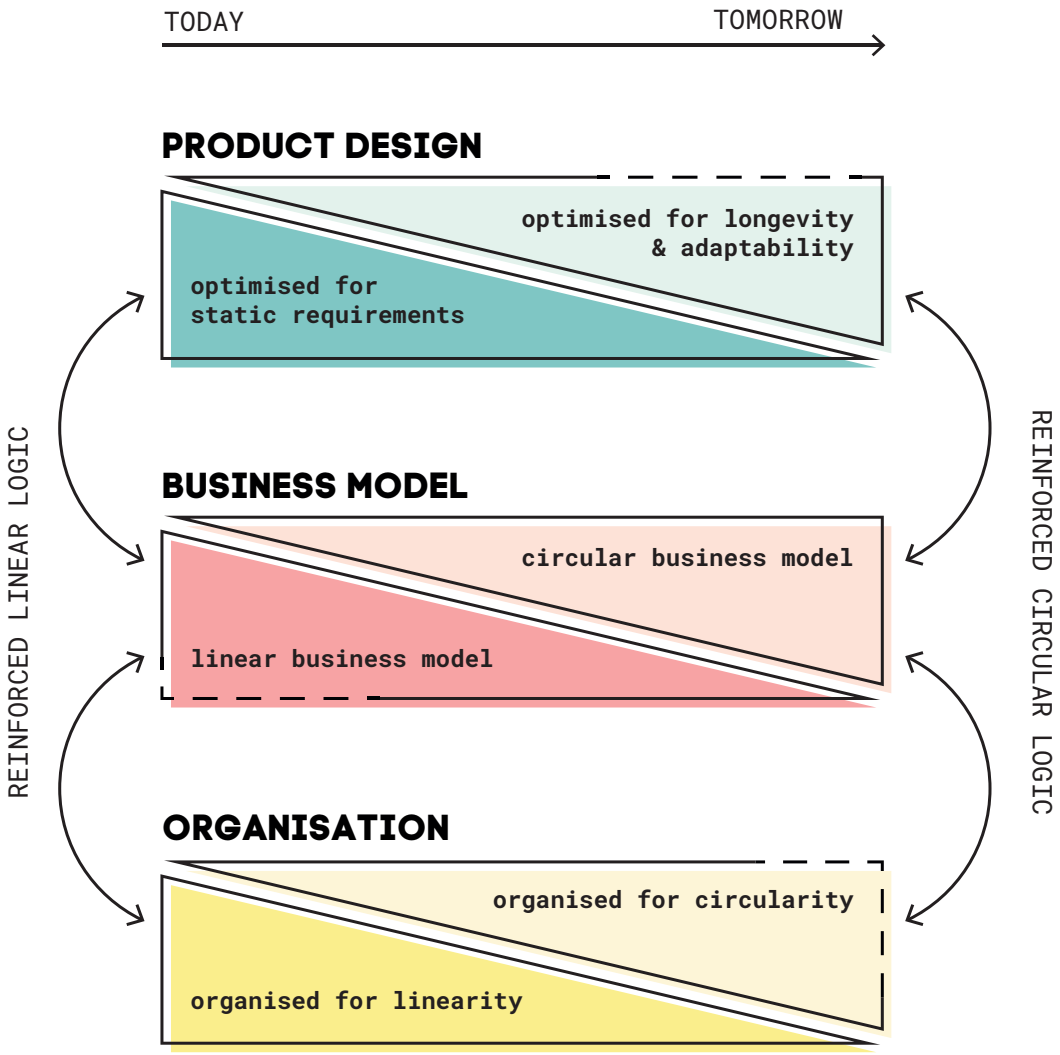
Shifting from a linear to a circular logic is a multi-dimensional transformation

In a world where most business models and organisations focus on low-cost production, point of sales, and lowest purchase price, it is challenging to design longer-lasting products while staying competitive. If the dominant business and organisation logics are built on linear thinking, products designed for longevity and adaptability may not make sense today. In order to shift to a more circular design logic, companies will also need to transform their business models and their organisational structure and culture.

The FAD approach facilitates internal company discussions and supports companies to align their design, business, and organisation logics. The framework provides a common language for designers and business developers to explore how profitability and product longevity can go together and also highlights what implications this will have for the overall organisation. By helping to reinforce a circular logic focused on longevity through the organisation, FAD can contribute to the multi-dimensional transformation that a shift from linear to circular logic requires.

Shifting from a linear to a circular logic may be more challenging for some companies than others. Incumbents with well-established design, business and organisation logics, may find the transformation complex and unmanageable, whereas startups may find it easier to adopt circular logics while experimenting and scaling their businesses. Most manufacturing companies will however face challenges since it is probable that colleagues, subcontractors and other business partners have not yet started their circular journey and may be reluctant to change the way they do things. Shifting from linear to circular is hence not only a multi-dimensional challenge for a singular company; a transformation of the sector may be required to reinforce a circular logic across value networks and business ecosystems.

Despite the challenges that designing for longer product lifetimes entail, we believe that it will soon become even more challenging to stick to a linear logic with normal lifetimes. We hope that FAD principles will help you and your organisation on the path towards ensuring long-term profitability and value capture within the limits of the planet. To develop successful and future adaptive circular offerings, we recommend that you work with all seven activities discussed in this guide so that you integrate a mindset for value preservation throughout the organisation. Business transformation takes time, so start now!



Curious to know more?

The FAD framework and approach have been developed by RISE and evolved over the past 10 years through several cross-functional research projects in close collaboration with industry. The approach and methods build on insights from our research as well as theories and frameworks from others in fields such as design for sustainability, industrial ecology, business development and organisational change. We have teamed up with industry partners from different sectors, such as the automotive industry and the furniture industry, to test ways of working and expand our understanding of what is needed for companies to create longer-lasting products for circular offerings.

If you want to know more about our research on Future Adaptive Design and the intersection between design and circular business models, read more about our research on www.ri.se under the expertise *Future adaptive design for a circular economy*.

Check out our previous academic publications:

Nyström, T., Whalen, K.A., Diener, D., den Hollander, M., & Boyer, R.H.W. (2021) Managing Circular Business Model Uncertainties with Future Adaptive Design. Sustainability,13, 10361.

Nyström, T. (2019) Adaptive Design for Circular Business Models in the Automotive Manufacturing Industry. Thesis for the degree of Licentiate of Philosophy in Design at HDK – Academy of Design and Crafts, Faculty of Fine, Applied and Performing Arts, University of Gothenburg, Sweden.

Diener, D., Nyström, T., Mellquist, A-C., Jonasson, C., & Andersson, S. (2019) The legend of the circular tire: Creating a vision for a more resource productive tire business ecosystem. In Proceedings of the 3rd PLATE Conference. Berlin, Germany.

Get in touch!

You are also most welcome to reach out to any of us if you are curious about how you can work with Future Adaptive Design. Our team of experienced researchers and business coaches can offer practical support and proven methods and tools that can help you to lower product-related business risks, combat product obsolescence, and realise the potential of circular business models. We are happy to help you work with Future Adaptive Design in practice.

Let's explore opportunities for longevity and circular business models together!

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Acknowledgements

The FAD approach presented in this guide has been developed by RISE Research Institutes of Sweden in collaboration with several companies and organisations.

The core team at RISE (including previous employees) that has been involved in developing the FAD approach and the content of this guide includes:

- Thomas Nyström, Researcher Design for Circular Business Models
- Anneli Selvefors, Researcher Design for Sustainability
- Derek Diener, Researcher Industrial Ecology
- Peter Algurén, Circular Transition Coach
- Lukas Hallquist, Innovation Leader
- Markus Eriksson, Researcher Business Transformation
- Katherine Whalen, Researcher Design for Circular Business Models
- Robert Boyer, Researcher Sustainable Business
- Josefina Sallén, Circular Transition Coach
- Marcus Linder, Research manager
- Mats Williander, Research manager
- Sofia Ohnell, Researcher Innovation Management
- Johan Östling, Project manager
- Kristina Andersson, Researcher Legal

The guide was developed in collaboration with a team at IVL, the Swedish Environmental Research Institute, including:

- Lisbeth Dahllöf, Expert in Environmental Systems Analysis
- Adam Lewrén, Expert in Life Cycle Assessment

The following partner organisations have contributed valuable insights and tested variations of the methods and tools described, which has helped us to further develop the FAD approach and tools as well as this guide:

- Hydroware
- Polestar
- Volvo Group Truck Technology
- Volvo Trucks

Additionally, several other organisations have taken part in exploring or discussing FAD opportunities, which have enabled us to increase our understanding of possibilities and challenges from different perspectives and in a variety of sectors. These organisations include:

- Accus
- Brighteco
- Dalform
- Future Eyewear
- Helly Hansen
- Normarkens fasader
- Ragn Sells
- Saab
- Sandvik Coromant
- Skistar
- Systembolaget
- Toyota Material Handling
- Vidde Snow Mobility
- Volvo Cars
- Volvo Construction Equipment

During our research projects, other researchers and industry representatives in our reference groups have contributed valuable insights and feedback that have spurred us to further develop the concept of FAD:

- Karin Andre, Volvo Cars
- Nancy Bocken, Maastricht University
- Marcel den Hollander, Maakindustrie Hogeschool
- Erik Sundin, Linköpings Universitet
- Markus Zils, University of Exeter

Swedish Energy Agency

Swedish Agency for Economic and Regional Growth

Several of the research projects that has contributed to the development of FAD have been founded by the Swedish Energy Agency. Moreover, some parts of this guide and the FAD tools have been developed as part of the Green Transition Leap for companies funded by The Swedish Agency for Economic and Regional Growth.

In this guide, we present practical strategies for designing products with extended lifetimes tailored for circular business models. Such circular models hold the potential to preserve and capture embedded values in products over time to contribute significantly to reduced climate and environmental impacts.

Increasing product lifetimes is also in line with emerging global trends and legislation that will increase pressure on manufacturers to enable repair, provide spare parts, and disclose expected product lifetime. Moreover, material and component shortages and price volatility along with growing consumer awareness worldwide compel companies to deliver longer-lasting products.

The methods and tools for Future Adaptive Design presented in this guide have been developed by us at RISE in close collaboration with industry partners through several cross-functional research projects. The approach builds on insights from our research as well as theories and frameworks from other researchers in fields such as Design for Sustainability, Industrial Ecology, Business Development and Organisational Change.

We hope that the principles outlined in this guide will help your organisation navigate towards increased circularity, where profitability and sustainability can go hand in hand.